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COLORADO RIVER DRAINAGE BASIN

Public Health Service
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Water Pollution Series, No. 9

For Clean Water—"One River, One Plan"

Colorado River
DRAINAGE BASIN

A COOPERATIVE STATE-FEDERAL REPORT ON WATER POLLUTION

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FEDERAL SECURITY AGENCY

Public Health Service

61

SUMMARY REPORT ON WATER POLLUTION

PB 229124

Colorado River Drainage Basin

Prepared by

FEDERAL SECURITY AGENCY
Public Health Service
Division of Water Pollution Control
Western Gulf and Colorado Drainage Basins Office

1951

In cooperation with

Arizona State Department of Health
California State Department of Public Health
Colorado State Department of Public Health
Nevada State Department of Health
New Mexico Department of Public Health
Utah State Department of Health
Wyoming State Department of Public Health

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INTRODUCTION

The Federal Water Pollution Control Act, Public Law 845, passed by the 80th Congress in June of 1948, requires the Surgeon General of the Public Health Service to cooperate with other Federal agencies, with State and interstate water pollution control agencies, and with municipalities and industries in the preparation or adoption of comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof, and improving the sanitary condition of surface and underground waters.

In developing these programs, due regard must be given to improvements necessary to conserve the Nation's waters for public water supplies, propagation of fish and aquatic life, recreational purposes, agricultural, industrial, and other legitimate uses.

Recognizing the fact that full technical information was not available to permit the development of such comprehensive programs immediately for most of the Nation's waters, the Public Health Service envisioned the development of these programs in two general phases. The first phase contemplated the development of a series of reports, consistent with presently available data, which would: provide a reference point for measuring progress; provide a guide to needed additional data; provide a basis for the logical development of comprehensive programs; provide a basis for approval of loans to States, interstate agencies and municipalities at such time as the Congress made available funds for this purpose; and serve to inform the public on the problem of water pollution and set forth suggestions for pollution control.

The collection of available data as of July 1, 1950, has been completed under the first phase of the program. Such data have been assembled with the cooperation of State and interstate water pollution control agencies. Through these agencies additional data have been obtained from other State officials, county and city officials and representatives of industry. Federal agencies also have been of great assistance. In order to make this information available at the earliest possible moment, these data are being presented in 15 summary-type reports covering the United States by major drainage basins. This report on the Colorado River Basin is one of that series.

These summary reports present information about the ways our water resources are used, the pollution going into our water resources and the resulting damages, the benefits which may result from pollution prevention and abatement, the pollution prevention measures now in effect, and those required.

They are prepared in two parts. Part One considers the water pollution problems of the basin as a whole. Part Two presents briefly the data for each of the several sub-basins of the major basin, including a list of projects now known to be needed for water pollution control.

Since the summary reports are based on data which are now readily available, these reports do not discuss or evaluate the most advantageous water uses as they are related to pollution control. Such considerations will be included as a part of the comprehensive water pollution control programs.

The deficiencies in data and the gaps in information indicated in these summary reports are as significant as the presentation of available facts and statistics. They indicate the work which still needs to be accomplished by water pollution control authorities for the preparation of comprehensive programs.

Data and knowledge now available are sufficient, however, to permit the immediate solution of many of the pollution problems within the Colorado Basin without awaiting the results of additional surveys and studies. The tabulations of pollution abatement projects which are included in Part Two of this summary report represent presently known needs. However, future studies and evaluations may result in some changes in estimations of requirements.

A sincere effort has been made by all who contributed to this report to present a fair picture of the complex water pollution problems in the Colorado Basin and to present reasonable conclusions and recommendations. It is our hope that this report, as a step in the cooperative development of an ultimate comprehensive pollution control program, will help in safeguarding the water resources of the Colorado Basin.

Leonard A. Scheele

Surgeon General

ACKNOWLEDGMENTS

The Public Health Service wishes to acknowledge the cooperation and assistance of those agencies and individuals that have contributed to the preparation of this report.

The water pollution control agencies of the States in the basin, including the Arizona State Department of Health, the California State Department of Public Health, the Colorado State Department of Public Health, the Nevada State Department of Health, the New Mexico Department of Public Health, the Utah State Department of Health, and the Wyoming State Department of Public Health, have furnished the data from which the various tables were prepared and other data and information contained in the narrative statements. These agencies have also reviewed the preliminary draft of the report and have offered valuable comments and suggested changes. In general, the preliminary draft has been revised so that the report is in agreement with the comments and suggestions of the State agencies.

Federal agencies from which assistance was obtained include the Corps of Engineers, Department of the Army; the Fish and Wildlife Service, the Geological Survey, the Bureau of Reclamation and the National Park Service, Department of the Interior; the Soil Conservation Service, Department of Agriculture; and the International Boundary and Water Commission.

Finally, there is acknowledged the assistance of other State agencies and individuals interested in water resources development and conservation, that have contributed information through sources other than those listed above.

SUMMARY

The Colorado River drains an area of 244,000 square miles or about one-twelfth of the area of the United States. Included within the basin are all of Arizona, the entire slopes of western Colorado, New Mexico and Eastern Utah, as well as small portions of Wyoming, Nevada and California. Approximately 2,000 square miles of the basin lie in the Republic of Mexico, but are not included in this report.

Each of the seven sub-basins within the Colorado River Basin contains interstate waters. Two tributaries of the Gila (the Santa Cruz and San Pedro Rivers) and the mainstem Colorado are international waters as well. There are no known instances, however, wherein man-made pollution, as contrasted with natural pollution, creates problems of interstate importance.

The present population of the basin is estimated at 1.2 million, with an average population density of 5.0 inhabitants per square mile.

Mineral, agricultural and forest lands, and water are the natural resources underlying the basic economy of the basin. The principal industries, and to a lesser extent the profitable "tourist industry," are dependent upon these natural resources. Future development of the basin rests largely upon greater conservation and utilization of its water resources for irrigation of additional lands and for the generation of hydroelectric power.

Agriculture and mining are the two important industries in the Colorado Basin; while irrigation constitutes the chief use of the water in the area.

Agriculture is completely dependent upon irrigation except in the headwater areas. Approximately 7,000,000 acre-feet of water for irrigation purposes and 270,000 acre-feet for domestic purposes are used in or exported from the basin annually. Domestic and industrial uses receive far less water and, in general, have lower priority rights, since the irrigation interests filed earlier claims to virtually all available water.

The generation of hydroelectric power, although a major factor in the basin economy, is incidental to storage and release of water for agricultural uses. The Colorado River Compact specifically states that the hydroelectric power demands shall be subservient to the use and consumption of water by the dominant interests--which include agricultural, domestic and industrial uses.

The quality of water is sufficiently high throughout the Colorado River Basin to serve all present uses with but a very few, and highly localized, exceptions. In many locations, silt and mineral salt concentrations are undesirably high but not sufficient to preclude present use of the water.

Although natural pollution of the flowing waters of the Colorado River Basin by erosion silt is a problem of major magnitude, it has not yet precluded the use of water for most purposes. Throughout the arid sections of the basin, water is so scarce that the presence of silt in high concentrations, while undesirable, is accepted. Silt has, however, increased enormously the maintenance costs for irrigation works and is slowly filling many of the storage reservoirs which are vital to the basin's agricultural economy.

At present, water pollution from man-made sources is not a basin-wide problem of great magnitude, since it is restricted to a few localized areas. Because both ground and surface waters are, in general, limited and often subjected to repeated usage, water pollution could become a very serious problem, unless the pollution which would follow any material increase in the population or the industrialization of the basin was not controlled. To offset this possibility and because of the present scarcity of water, the development of a comprehensive water pollution control program designed to protect the quality of water for all present and future uses is needed.

As a result of the extensive development of storage reservoirs and the operation of dams and control works, flow conditions in long reaches of many of the rivers are under almost complete regulation. This regulation is controlled to satisfy demands for agricultural, domestic and industrial uses and water is available for dilution of sewage and industrial wastes only when released for other purposes.

At the present time there are 193 sewered municipalities within the Colorado River Basin serving about 593,000 people--approximately 50 percent of the total population. Only 34 of the sewered communities lack sewage treatment facilities. The 160 sewage treatment plants in the basin serve approximately 535,000 people--or slightly over 90 percent of the sewered population. Of these 160 plants, only 75 are considered of satisfactory design capacity for current loadings and only 83 are reported to be operating at an

acceptable level. Information is not in sufficient detail to indicate the corrective measures needed to improve operation.

The industrial waste picture of the Colorado Basin is far from clear. It is known that 330 industrial plants are discharging waste directly to the watercourses through separate outlets--how many more there may be is not known. Thirty-one of these are known to have some form of waste treatment facilities and 39 are known to definitely lack such facilities. At the remaining 260 industrial plants no determination has been made of the existence of waste treatment facilities. A more complete and accurate survey of the industrial waste pollution in the basin must be secured to enable the development of a comprehensive stream pollution abatement program.

It is estimated that construction of the facilities requested by the State pollution control agencies for abatement of sewage pollution will cost approximately $11,000,000. These requirements include 34 new plants, additional treatment facilities at 31 plants, and the replacement of 53 existing plants.

This cost estimate was prepared on the basis of the July 1950 construction cost index. It does not include such items as land, right-of-way, sewers, piling, etc., the cost of which varies with local conditions. Neither does it include operation and maintenance cost.

Of the 118 municipal project requirements, one will serve a population over 14,000, 11 will serve populations between 5,000 and 10,000 and 42 will serve between 1,000 and 5,000. Sixty-four of the required projects will serve populations of under 1,000, 44 of which are to serve populations under 500.

The presently determined requirements for industrial waste pollution abatement consist of 14 new waste treatment plants, enlargements or addition to two existing plants and the replacement of four others. There are 299 industries for which no determination has been made as to the pollution abatement measures necessary. Available information is not sufficient to allow for estimating the cost of these industrial waste treatment projects.

Existing State legislation is discussed under "Pollution Prevention Measures in Effect."

A marked increase in the construction of sewage treatment facilities occurred during the last four years. A single plant with a design capacity of 500 was completed in 1946, in comparison with nine plants, with a combined population design of 265,000 completed during 1949. During these four years, a total of 14 sewage treatment plants, serving a combined population of over 285,000, were completed. No industrial waste treatment plants are known to have been constructed during these years.

CONCLUSIONS

1. Most of the basin is semiarid or arid and agriculture is dependent upon surface and underground waters to supplement the scant rainfall.

2. The major uses of waters in the Colorado River Basin are for irrigation and domestic water supply. Recreational use is important in the headwaters areas and at some of the reservoirs.

3. Future development of the Colorado River Basin will depend, in large measure, upon the availability of water of suitable quality.

4. Flow conditions in long reaches of many of the rivers of the basin are under virtually complete regulation by dams and control works, and little water is available for dilution of sewage and industrial wastes.

5. A sound basin-wide comprehensive program of Water Pollution Control is needed to assure that in the future the quality of the waters will be acceptable for all water uses.

6. Basic information on industrial waste pollution must be secured to permit the development of a comprehensive Water Pollution Control program.

7. There is practically no data available on the self-purification characteristics of the streams, the extent of damage to the waters from pollution during critical periods, or the degree of waste treatment required to provide the quality of water necessary for downstream water uses.

8. Major damages to the waters from silt and mineral salts occur throughout the basin.

9. Heavy silt pollution interferes with use by siltation of reservoirs and the aggradation of irrigation works and stream beds.

10. Pollution from natural salts restricts both actual and potential uses of the waters in the lower reaches of the Virgin, Little Colorado, and various minor tributaries of the basin.

11. Producing oil wells are not as yet contributing significant pollution to the waters of the basin. They are a potential source of brine pollution and may produce salt wastes as the oil reserves are depleted.

12. Pollution effects from industrial and municipal wastes are, in general, confined to a few localized areas immediately below or adjacent to waste outlets to the streams.

13. Approximately 50 percent of the basin population is served by public sewer systems and over 90 percent of persons served by public sewers are also served by sewage treatment plants.

14. Approximately 60 percent of the municipalities in the basin require new or additions to treatment facilities.

15. The State water pollution control agencies in the Colorado River Basin need additional technical personnel and funds to develop and carry out a comprehensive pollution abatement program.

RECOMMENDATIONS

It is recommended that:

1. A comprehensive program for Water Pollution Control be developed for the Colorado River Basin so that the most beneficial uses can be made of the water resources.

2. Waste treatment facilities now known to be needed be constructed at an early date and required pollution corrective measures be established as soon as possible.

3. Basic information now lacking on industrial waste pollution and water use be obtained as soon as possible in order to expedite the development of a comprehensive Water Pollution Control program.

4. The extent of damage from pollution to the water resources during critical periods be determined so that the degree of treatment required to maintain the desired water quality can be established. Establishment of the self-purification characteristics of the streams are necessary for these determinations.

5. Quality standards for irrigation waters be developed at the earliest possible date, since such standards are prerequisite to an assessment of existing pollution damages to irrigation waters as well as for a determination of the degree of waste treatment required to maintain acceptable water quality.

6. The State water pollution control agencies consider the effects of pollution on all water uses in developing comprehensive programs. Where changes in existing State water pollution legislation may be necessary to empower the State agencies to do this, such legislation should be enacted.

7. All groups and individuals, having an interest in water use and pollution control, cooperate with the water pollution control agencies in developing and carrying out public informational programs on water pollution control.

8. State legislatures provide sufficient funds to the State water pollution control agencies so that they may increase their technical staffs, expedite the development and conduct of a comprehensive Water Pollution Control program, develop sound informational programs for the public and for industry, and promote community planning of pollution abatement measures.

9. Sewage and waste treatment plant maintenance and operation be developed to a high level so that maximum returns may be realized from investments in treatment facilities.

10. Soil conservation programs be expanded and accelerated in the basin where they can be expected to have a significant effect in reducing stream siltation.

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LOCATION MAP

Colorado River Drainage Basin

GENERAL DESCRIPTION

Historical Background

Spanish conquistadors, and priests exploring north from Mexico in search of gold and converts, were the first white men to enter the basin. The mouth of the Colorado River was discovered in 1540 by Hernando de Alarcon, who explored the stream to a point about 100 miles above the mouth of the Gila River. Two years later the Grand Canyon was discovered, but the explorers were unable to descend its sheer walls. The early explorers found the country inhospitable and the problems of obtaining food and supplies virtually insurmountable, so that following the earliest--and fruitless--quest for gold, the basin was largely avoided by the white men for two centuries. Only the priests were active during this time and the early knowledge of the country resulted largely from their untiring efforts. These missionaries influenced early settlement of the basin. Father Kino, a Spanish priest, founded the first settlement in the Colorado Basin, following a visit to the region in 1691. The Spaniards established Resident Fathers in the Santa Cruz River Valley as early as 1700, and soon after several missions were constructed on the banks of the stream.

Traders, trappers and explorers entered the northern area from the east about 1820 in search of beaver and gradually worked their way south. By 1840, the wilderness had been traversed throughout by white men except for the deeper canyons of the Colorado. About 1840, the beaver became so depleted that trapping was no longer profitable. The treaty of Guadalupe-Hildalgo, signed in 1848 at the end of the war with Mexico, and the Gadsden Purchase in 1853 provided the United States with much of the territory now included in the seven Colorado River Basin States.

Among the early colonizers of the basin were Mormon pioneers, who settled in small agricultural communities along valleys, cultivated the more favorable farming lands adjacent to streams where irrigation water was readily accessible, and grazed livestock on nearby range lands. Old Fort Supply in Wyoming and Santa Clara, Utah were established by Mormons in 1854 as outposts in their Desert State.

The lure of gold was one of the chief factors influencing the early settlements. Many pioneer settlers came in search of gold but remained to raise livestock and to farm. Where valuable mines were discovered, communities developed in their immediate vicinity and, where possible, irrigated agriculture was practiced nearby to supply the demands of local markets. Cattlemen were attracted to the expansive grazing areas of the basin and in many sections were the first settlers.

Physical Characteristics

The Colorado River rises high in the snow capped Rocky Mountains of north central Colorado and flows nearly 1,400 miles generally southwesterly, to empty into the Gulf of California in the Republic of Mexico. It is the second longest river in the United States outside the Mississippi River system. This mighty river has gouged the rock of the mesas into fantastic gorges and chasms, the most spectacular of which is the world-famous Grand Canyon in Arizona, a titanic cleft over 200 miles long, as much as 18 miles wide, and over one mile deep.

The Colorado River drains a vast area of 244,000 square miles: 242,000 miles in this country--or an area one twelfth that of the Continental United States--and 2,000 square miles in northern Mexico, not included in this report. The basin as covered by this report also includes certain bordering desiccating basins in southeastern Arizona and western New Mexico which increase the total basin area to about 249,255 square miles. In airline distance, the basin from the Wyoming headwaters to the mouth measures approximately 900 miles in maximum length and varies in width from about 300 miles in the upper section to 500 miles in the lower section. It is bounded on the north and east by the Continental Divide of the Rocky Mountains, on the west by the Wasatch range, and on the southwest by the San Jacinto Mountains, of the Sierra Nevadas. Tributaries drain from seven large Western States namely: Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming.

The upper, or northern, portion of the Colorado River Basin in Wyoming and Colorado is a mountainous plateau, 5,000 to 8,000 feet,in altitude, marked by broad rolling valleys, deep canyons, and intersecting mountain ranges. Hundreds of peaks in these mountain chains rise to more than 13,000 feet above sea level and many exceed 14,000 feet. There are many picturesque mountain lakes in the headwater sections. The southern portion of the basin is characterized by rugged mountain peaks, interspersed with broad, level, isolated mesas, rolling plateaus, and desert wastelands.

The Colorado River proper is formed by the drainage from three principal watersheds: the upper Colorado, the Green and the San Juan. Innumerable smaller tributaries, some of them draining vast areas, join the river system but, owing to the arid climate of these areas, individually contribute comparatively little to the firm flow of the main stem.

The upper Colorado, fed by the permanent snows on the west slope of the Continental Divide of western Colorado, flows southwesterly with a steep gradient through a series of steep canyons and narrow valleys to meet the Green at River Mile 1,010. At this point, both rivers have eroded a canyon 2,200 feet deep into the surrounding high plateau--a canyon from which the river does not emerge for 950 miles downstream. The Green, rising in the mountains of southern Wyoming, flows southward across a succession of broad plateaus and escarpments. At River Mile 870, the San Juan, flowing through narrow valleys and almost across the famous "Four Corners" of Colorado, Utah, New Mexico, and Arizona, joins the main-stem. At this point, the Colorado River plunges into Glen Canyon and subsequently into the Grand Canyon. Below the Grand Canyon, the river meets Lake Mead, the reservoir behind Hoover Dam and the largest man-made lake in the world. Below Hoover Dam, the river traverses the Colorado Desert and emerges from its long canyon as it crosses into the Republic of Mexico to flow across the wide alluvial delta which its silt has built into the Gulf of California.

The more important tributaries, joining the Colorado through its long canyon reach, are the Little Colorado, an intermittent stream draining western New Mexico and eastern Arizona, the Muddy and Virgin Rivers which contribute their small flows directly to Lake Mead, the Bill Williams River, and the Gila River which--although it drains virtually all of southern Arizona--seldom contributes any water to the Colorado. For example, no flow was recorded at the mouth of the Gila between 1941 and 1947.

The flora and fauna of the Colorado River Basin are many and varied, ranging from alpine to desert species. The high areas of the headwaters are covered with forests of pine, fir, spruce, and silver-stemmed aspens, broken by small glades and mountain meadows. Pinyon and juniper trees, interspersed with scrub oak, mountain mahogany, rabbit brush, bunch grasses and similar plants grow in the intermediate elevations of the mesa and plateau regions. Scattered cottonwoods and chokecherries grow in the canyons with the cliff rose, the redbud and blue columbine. A profusion of wild flowers carpet the many mountain parks. In the lower region, large areas are almost completely devoid of plant life, while other sections are sprinkled with desert shrubs, Joshua trees, Yucca plants, and saguaro cacti, some of the latter reaching 40 feet in height. Occasionally salt cedar, cottonwoods and desert willows are found along desert streams together with mesquite and creosote bush or catclaw and paloverde.

The Colorado River Basin is the natural habitat of bighorn sheep, ptarmigan, and wild turkey. Deer, elk, and antelope are found in the forested and more primitive areas. Mountain lions, wild cats, lynx, and other predatory animals are fairly common in remote areas. Coyotes inhabit the plains country where they prey on gophers, cottontails, jackrabbits, and other smaller mammals. Furbearing animals in the mountains include beaver, fox, badger, ermine, muskrat, skunk, and mink. Duck, geese, snipe, white-wing pigeons, quail, dove and other game birds are numerous. Snakes, lizards and other reptiles are frequently found in the desert areas.

The cold clear mountain streams abound in trout, the most common varieties being rainbow, eastern brook, cutthroat and Loch Leven. Bass, crappie and bluegill prefer the lakes and reservoirs to the moving waters of the streams.

Climate - Hydrology

Climatologically, the Colorado River Basin has the extremes of year-round snow cover and heavy precipitation on the high peaks of the Rockies, snow capped eight to ten months a year, to the truly desert conditions with very little rain in the southern area around Yuma, Ariz. The wide range of climate in the basin is caused largely by differences in both altitude and latitude.

Extremes of temperatures in the basin range from -50°F. to 130° F. The northern portion of the basin is characterized by short warm summers and long cold winters. The southern portion of the basin experiences long hot summers, practically continuous sunshine and an almost complete absence of freezing temperatures.

The entire basin is arid except in high altitudes of the headwaters areas. Rainfall generally is insufficient for the profitable production of crops without irrigation. Along the Mexican border, the annual precipitation averages only 2.5 inches, while in the higher mountains of Colorado, Wyoming, and Utah, the average may reach 40 inches. In the northern part of the basin most precipitation occurs in the form of winter snows and spring rains. Summer storms are infrequent, but when they occur are sometimes of cloudburst

intensity in localized areas. Winds of high velocity are common in some sections.

The stream pattern of the Colorado River might best be considered in two parts, the uncontrolled flows which occur in the river above Hoover Dam, and the flows below this impoundment which are completely regulated. The average annual flows of the Colorado above Hoover Dam vary from 100 cubic feet per second in the extreme headwaters to 8,193 second-feet as the river joins the Green which itself contributes 6,722 second-feet. The flow increases to an annual average of 17,350 second-feet as the river crosses the Arizona-Utah border and to 17,710 second-feet when the river reaches Lake Mead. These average annual flows do not indicate the extremes during the year. The flow into Lake Mead may be as low as 700 cubic feet per second and during floods may reach as high as 300,000 cubic feet per second.

Below Hoover Dam, four river gaging stations at progressive intervals downstream show a continuous diminution of the flow due to withdrawals for irrigation and public water supply, and loss through evaporation. These decreasing controlled flows normally range from 13,960 cubic feet per second immediately below the dam to 9,153 cubic feet per second as the river enters the canal system above Yuma, Ariz. The variations in discharge from Hoover Dam have ranged from zero, when all water is being stored, to 51,200 cubic feet per second at times of maximum release.

The length of growing season varies from about 80 days at the higher elevations of the northern mountainous sections to year-round in the lower semitropical southern areas. Although the growing season of the high agricultural areas in the northern section of the basin are short, air drainage in localized sections along the foothills of the lower valleys is favorable for the growing of fruits such as peaches, pears, cherries, apricots and berries. Because of the long growing season in the lower regions of the southern portion of the basin, double-cropping is commonly practiced in the principal farming districts where enough irrigation water is available.

Farming by irrigation as now practiced in the Gila and Salt River Valleys are revivals of an ancient aboriginal agricultural development. Present canals in many instances closely parallel an ancient canal system which, it is estimated served some 250,000 acres. The cause of the final exodus of the original tribes from the region is not known, but it is believed to have been severe and prolonged drought.

Economic Development

The Colorado River Basin remains one of the most sparsely settled areas of its size in the Western Hemisphere. The present population is estimated at 1.2 million which represents a density of 5.0 persons per square mile. The three largest cities in the basin are Phoenix, Tucson, and Mesa, with populations (1950) of 105,000; 44,400, and 15,950 respectively. No other city in the basin has a population exceeding 15,000. The population concentrations are limited to areas which can be irrigated, mined, or which hold special attraction such as railroad or tourist centers.

Many of the dams and other man-made reservoirs are centers of interest to the sportsmen and other persons interested in outdoor activities in the arid regions of the basin. The streams in the head-water areas are also major attractions for sportsmen, campers and hunters. The value of these waters cannot be overemphasized in an area as arid as the Colorado River Basin.

The Grand Canyon, Petrified Forest, Bryce Canyon, Zion National Park, Mesa Verde National Park, Hoover Dam, San Xavier Mission, and many other nationally known scenic attractions are the backbone of a profitable tourist business. The warm, dry, sunny climate in the southern part of the basin also draws a heavy tourist trade. The healthful climate, the scenic beauty and the excellent hunting and fishing has resulted in a recreation and tourist industry of such magnitude that it now ranks with mining and agriculture as one of the three leading economic activities of the basin. Clean water, free from pollution, is of vital concern to all persons dependent upon the tourist trade.

Agricultural products of the basin include cattle and sheep from the vast range areas and irrigated hay meadows of Wyoming, Colorado, Utah, New Mexico and Arizona; temperate-climate fruits from Colorado; and citrus fruits, winter vegetables, livestock and hay from the Phoenix-Yuma areas. In 1946 there were 2,260,000 acres under irrigation in the Colorado River watershed. This represents only 1.7 percent of the total land area of the basin, but it is the maximum that can be irrigated feasibly with present impoundments and available water.

Industrial development, except for mining, does not constitute a major economic activity of the basin.

The enormous beds of varying grades of bituminous coal within the basin in eastern Utah, southern Wyoming, and western Colorado are estimated to contain nearly one

fourth of all the coal reserves of the United States. Mines in these areas now supply most of the coal requirements in the Rocky Mountain and Pacific Coast areas, including the requirements for the transcontinental railroads and the Utah and California steel industries. Vast deposits of oil shale and bituminous sandstone are undeveloped, but are becoming increasingly important. Natural gas from basin fields in Wyoming, Colorado, and New Mexico supplies local needs and industrial needs in areas outside of the basin. Mines in Utah and Colorado are the leading domestic source of vanadium, uranium, radium, and molybdenum. Since 1910 Arizona by its mines and ore reduction mills located within the basin, has constantly led all States in copper production. Gold, silver, and several other metals, largely by-products of copper mining, are recovered in important quantities. Great beds of thinly covered phosphate rock centering around the corner common to Utah, Wyoming, and Colorado provide a basis for a potential fertilizer industry.

In the entire upper basin, above Lees Ferry, Ariz., development of hydroelectric power amounts to but 60,000 kilowatts. In the lower basin, however, the Hoover Dam and Parker Dam power plants, the power plants on the Salt River near Phoenix, and various lesser hydroelectric developments, have an aggregate installed capacity of 1,258,000 kilowatts, or roughly 50 percent of the dependable capacity available to the Southern California-Arizona area. (Source: The Colorado River, A Comprehensive Report on the Development of the Water Resources of the Colorado River Basin for Irrigation, Power Production, and Other Beneficial Uses in Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming, Bureau of Reclamation, Department of the Interior--March 1946).

USES OF WATER RESOURCES

The waters of the Colorado River Basin are used principally for irrigation, public water supply, power generation, and recreation. They are used, to a very limited extent, by industry for processing, concentrating and refining minerals, and for food processing. Irrigation is, by far, the major use of waters from both surface and underground sources.

Throughout the entire basin, a total of 236 communities, with a combined population served estimated at 630,000, utilize water from surface, ground or combination sources. Of these, 47 communities supply 101,000 inhabitants with 21 million gallons of surface water per day, 51 communities supply 214,000 inhabitants with 37.5 million gallons of ground water per day, and 10 communities supply 137,000 inhabitants with 53 million gallons of water obtained from both surface and ground water sources. No municipal water use data are available for 99 communities using ground water, 23 communities using surface water, or 6 communities using combination sources. In those communities for which municipal water use data are available, the per capita consumption averages 247 gallons per day. This value is much higher than the national average, since it reflects an arid climate where much water is used for air conditioning and for irrigation of lawns and gardens.

In addition to the water used for municipal purposes within the basin, 145,000 acre-feet per year--or about 131 million gallons per day--now are exported for municipal use in the Metropolitan Water District of Southern California.

Industrial water use throughout the basin is mainly for processing coal and concentrating and refining metals. In general, water is so scarce at most mine and mill sites that it is recycled to the fullest extent possible and pollution from such process wastes is insignificant in comparison with that from natural soil erosion or even that from improperly located and unprotected spoil banks, and culm and tailings deposits.

Irrigation has been developed wherever it proved economically feasible to divert water from the streams to the rich but arid soils of the basin. In 1946, there were 2,260,000 acres under irrigation in the Colorado River Basin. In addition, 416,000 acres in the Salton Sea Basin of Southern California were being irrigated with Colorado River water and 184,000 acre-feet of water were exported to adjacent river basins in Colorado and Utah for irrigation, power, and municipal purposes. A total of about 7,000,000 acre-feet of Colorado River Basin water are used annually in the basin and/or exported to adjacent basins for irrigation.

The hydroelectric power industry is a large user of the waters of the basin. Power generation does not consume the water, but takes advantage of the head made available by high dams and after use passes the water on to other users. In 1946 the hydroelectric developments in the basin had a total installed capacity of 1,318,000 kilowatts.

Game abound in both the valley and mountain regions where water is available. The sportsman finds a plentiful supply of such big game as deer, elk, and bear in the forested and primitive areas. Mountain lions, coyotes, and other predatory animals are fairly common in remote areas. Numerous species of small game attract many local hunters. Game birds found in the basin include wild turkey, duck, goose, snipe, white-wing pigeon, quail, ptarmigan, and dove. Several national game refuges are located partly or entirely within the basin.

Many of the waters of the Colorado River Basin, particularly those of certain man-made lakes, teem with fish of many types. Trout are plentiful in the clear, cold water of the tributaries and mountain lakes, while bass, crappie and bluegills are present in many of the reservoirs. In the upper portion of the basin, approximately 2,500 lineal miles along 318 streams as well as 273 lakes constitute a fisherman's paradise. Lake Mead and numerous reservoirs of the basin are kept well stocked by the many fish hatcheries in the basin. The main stems of most rivers are, however, not productive fishing waters because of their tremendous silt loads, intermittent flows, or high mineral content.

The waters of the Colorado River Basin appear of adequate quality for all present uses, except for localized instances where the dissolved mineral content restricts agricultural use to the irrigation of salt-resistant crops. The heavy silt burden carried by most rivers of the basin, while not preventing its use, does increase the cost of maintaining irrigation works.

POLLUTION CONTRIBUTED TO WATER RESOURCES

The waters of the basin receive enormous quantities of pollution from natural sources in the form of silt and mineral salts. Silt pollution originates in virtually every part of the basin, except for the extreme headwater areas, and the effects are felt throughout the basin.

The unstable friable soil of the desert and arid portions of the basin is subject to serious erosion and the silt pollution of rivers draining the area is tremendous. Floods from summer cloudbursts pour silt laden torrents into the tributaries, which in turn deliver to the Colorado River the enormous quantities of silt that plague downstream water users. Most of the erosion and silt pollution is the result of natural conditions but overgrazing of range land has accelerated erosion in many areas.

The water entering Lake Mead is estimated to carry about 199 million tons of silt annually, all of which settles in the reservoir. The water discharged from Hoover Dam is reported silt-free at all times but the river rapidly accumulates another silt burden, estimated to be 3 million tons annually, by the time it reaches Yuma. This quantity represents an enormous reduction from the 180 million tons that the river is estimated to have carried at this point prior to the construction of the main-stem dams. It is estimated that the storage capacity in Lake Mead is being reduced by 137,000 acre-feet each year by the deposition of silt.

Some of the streams of the basin are heavily laden with mineral salts leached from the surrounding alkaline soils. Two rivers in particular have a dissolved mineral content sufficiently high to impair their waters for many uses. Mineral springs in the lower Virgin River render the water unsuitable for domestic purposes and unfit for irrigating other than the most salt-resistant crops. Salt, dissolved by the waters passing over natural salt-bearing formations, together with that poured into the rivers by mineral springs, so pollute the waters of the Little Colorado River that they are of questionable quality below St. Johns and, a short distance below Holbrook, become entirely unsuitable for irrigation.

In some areas within the basin the dissolved solids content of the waters has been increased by irrigation. The build up of salts occurs through concentration by evaporation and through the leaching of minerals from the soil.

Pollution from municipal sewage occurs in scattered areas throughout the basin and is of considerable concern to local health authorities, especially where it might affect ground water sources of domestic water supply. The extent of this pollution is not known, but the concern is illustrated by the fact that the pollution control authorities are requesting that sewage treatment facilities be installed or improved at 118 of 193 sewered municipalities.

Some localized pollution of surface water is believed to occur in certain intermittent streams and irrigation ditches as a result of the lack of convenient sanitary facilities. In addition, some nuisance conditions are reported as resulting from the discharge into dry washes of effluents of inadequate sewage treatment plants. These conditions are objectionable from the aesthetic standpoint and may result in the pollution of underground waters.

All but 34 of the 193 sewered communities in the basin have sewage treatment facilities and sewage from about 58,000 persons, about 10 per cent of the total sewered population, is being discharged without treatment. Most of the untreated sewage is discharged into streams which have sufficient time to recover from the effects of the pollution before being used as sources of public water supply. Recreational use of these waters has not been affected according to available information. Eighty-four of the existing 160 sewage treatment plants are antiquated and need enlargement or replacement if adequate treatment is to be secured. The operation of 62 of the plants was reported to be unsatisfactory, in many cases due in part, no doubt, to inadequate plant capacity.

There are 330 known industrial sources of pollution discharging waste directly to the watercourses of the basin. Seventy-three of these produce organic wastes, 20 produce inorganic wastes, one produces both organic and inorganic wastes and 237 are producing wastes of an undetermined type.

That the industries producing organic waste are small is evidenced by the fact that of the 52 industries which discharge a total organic pollution load with a population equivalent of about 279,500, one, a beet sugar refinery, contributes a population equivalent of 276,000 while the remaining 51 jointly contribute a population equivalent of only 3,500.

Wastes from mine operations and from mills concentrating ores and refining metals are reported to have affected some streams, although the actual amount of polluting materials entering the waters has not been determined. There are many instances where soil banks and culm and tailings deposits have been located near the streams. Loose materials have been washed into the streams and water seeping through these piles of wastes has leached out and carried to the streams minerals which may be detrimental to the waters. The amounts of these polluting materials reaching the streams and their effect upon the waters still must be ascertained.

Table A. Sources of pollution, municipal

Municipalities*	Sources of pollution (in number of municipalities)	Population served by sewerage system	Amount of pollution discharged to watercourse (in terms of equivalent number of people)**
Having data on pollution load discharged to watercourse	4	124,540	4,375
Having population data available (Data on pollution load to watercourse incomplete or not available)	189	468,897	Not applicable
Total	193	593,437	--

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

**Includes industrial wastes discharged into municipal sewerage systems.

Table B. Sources of pollution, industrial*

Industries	Sources of pollution (in number of plants)	Amount of pollution discharged to watercourse (in terms of equivalent number of people)
Producing organic wastes	42[1]	279,352[2]
Producing organic wastes	32	Undetermined
Producing inorganic wastes	20	Not applicable
Producing wastes of undetermined type	237	Undetermined
Total	330[3]	--

*Industries known to have separate outlets and discharging wastes directly to watercourse.

[1]Including one plant producing inorganic wastes as well.

[2]One beet sugar refinery produces wastes with a population equivalent of 276,250.

[3]Total adjusted to correct for duplication noted in footnote[1].

DAMAGES TO WATER RESOURCES FROM POLLUTION

Pollution to the water resources is caused by silt, dissolved mineral salts from natural sources, and industrial and domestic wastes. The most damaging pollutant to the water resources of the Colorado River Basin is silt originating from land erosion.

The poorly compacted friable soil found over all but the headwater areas of the basin, associated with sparse vegetation and torrential--if infrequent--rains, results in the tremendous silt loads, characteristic of virtually every stream below the mountain canyons. Except for the headwaters, the reservoir areas and streams stretches below dams, the streams are too turbid to provide an attractive wildlife habitat or to support those fishes desired by the anglers. The silty waters and the deep mud deposits along the banks and bottoms of the streams, as well as in many reservoirs, greatly restrict their recreational use and value.

The silt dropped from the water as flood charges recede aggrades the stream beds which complicates and greatly increases the cost of flood protection to adjacent lands and at railroad and highway bridges. Silt deposition likewise vastly increases the cost of maintaining irrigation which is not only the dominant use of water but one vital to the entire economy of the Colorado Basin. As an example of the increased cost of irrigation due to silt, elaborate desilting works costing $4,526,000 were constructed at the head of the All American Canal to eliminate the cost of repeated dredging which was totalling $700,000 annually. Ironically the silt removed from the waters going to the All American Canal are returned to the river. Silt is by no means in maximum concentrations at the All American Canal diversion, since the annual burden there is estimated at approximately 13-million tons in comparison with the 199-million tons carried by the river above Lake Mead. Siltation likewise is slowly filling the many impoundments of the basin which are essential to a sustained irrigation water supply during low-flow periods. The silt deposited in Lake Mead, for example, is estimated at 137,000 acre-feet annually.

Some siltation of headwater streams potentially valuable for recreation has developed from improperly protected mine tailings and culm. These problems are, however, of local significance and the State pollution control agencies have initiated action towards their effective solution.

Concentrations of dissolved salts from natural sources are sufficiently high in the lower reaches of the Little Colorado and the Virgin Rivers to exceed tolerance limits for both irrigation and domestic uses. In these particular areas, however, the natural terrain precludes use of the water for the above purposes.

The actual known damage to perennial natural watercourses by domestic or industrial waste pollution is confined to localized instances. Inadequately treated liquid wastes are often discharged into irrigation ditches, a practice which has created several highly offensive local nuisances. Such practices create health hazards for those isolated individuals who may use this water untreated for domestic purposes. In addition there are potential hazards accompanying the use of sewage contaminated water for irrigating crops that may be eaten uncooked.

In many cases, inadequately treated wastes are disposed in dry washes or to underground gravel strata which may offer a threat, of unknown magnitude, to the quality of the subterranean water resources.

BENEFITS RESULTING FROM POLLUTION PREVENTION AND ABATEMENT

The greatest benefits from pollution prevention and abatement in the Colorado River Basin would accrue from the general application of effective soil conservation measures. The reduction in reservoir replacement costs, maintenance of irrigation and flood control works, and the bridge protection would be enormous. In addition, several thousand miles of streams could be reclaimed for recreational purposes.

Insofar as man-made pollution is concerned, the benefits arising from corrective and preventive measures are mostly those intangible but nonetheless important values related to public health. Inadequately treated, or untreated, domestic sewage constitutes a constant hazard to public health.

The public health significance of irrigating with sewage contaminated waters has not been firmly established. Irrespective of the facts that eventually may be uncovered, the thought is repugnant to the average consumer and might easily lead to his refusal to buy fresh produce from those areas where polluted irrigation water is used. Such an eventuality would lead to economic hardship, particularly in the lower Colorado River Basin where off-season produce is grown in sharp competition with other regions.

The irrigation canals often serve as sources of drinking water for itinerant labor campers and field workers. Pollution prevention measures would lessen their chances of contracting waterborne diseases and spreading them to other regions.

POLLUTION PREVENTION MEASURES IN EFFECT

The control of pollution from municipal wastes has been well advanced by the State health departments in the Colorado River Basin. Approximately fifty percent of the entire population within the basin is served by public sewer systems and ninety percent of the sewered population are served by sewage treatment plants. As shown in table C, 76 of the 160 sewage treatment plants in the basin provide primary treatment and 84 provide secondary treatment.

Some of these plants, however, are obsolete and in need of replacement. Others, at the time of construction, were quite adequate for community needs, but subsequent population growths, brought about in part from wartime developments, have resulted in a need for enlarged or additional treatment facilities.

Analysis of State Water Pollution Control Legislation

The following analysis presents briefly the salient features of water pollution control legislation of the various States in the Colorado Drainage Basin. It is based on previous analyses of State legislation which were reviewed by the various States and used in the development of a Suggested Water Pollution Control Act which was subsequently endorsed by the Council of State governments and recommended to the States for favorable consideration.

California is the only State in the basin which has established specific boards to deal with the question of water pollution control. California has established nine regional water pollution control boards which have authority to control pollution within their districts, where the pollution does not create an actual hazard to public health. The State Department of Health has the duty of controlling contamination of waters which creates an actual hazard to public health through poisoning or spread of disease. The California State Water Pollution Control Board, which has general supervision over the regional boards, has the ultimate authority to enforce all water pollution control laws, whether they affect health or not. In all the other States in the region, the State health departments are given water pollution control functions as they affect public health. In addition, in Arizona, Colorado, Wyoming, and California the Game and Fish authorities have specific functions in relation to water pollution which affects fish.

Table C.
Existing treatment facilities, municipal

Degree of treatment provided	Number		Population served
	Municipalities*	Plants	
Primary	76	76	136,150
Secondary	83	84	398,846
No treatment	34	--	58,441

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

California is the only State which provides by statute for an executive officer to be in charge of the water pollution control program. In Arizona, however, a Division of Sanitary Engineering is required by statute to be set up within the State Department of Health.

California is the only State in the basin in which a comprehensive program is required by statute to be developed for the prevention, abatement, and control of pollution. Colorado is the only State in the basin where the water pollution control authority is empowered to set standards of water quality. None of the States in the basin is given the statutory duty to classify waters of the State according to use.

Wyoming is the only State in the basin which by statute requires permits after review of plans and specifications for the construction of all sewage systems and treatment works and extensions thereof. The Nevada statutes require such permits only for discharges into Lake Tahoe and its tributaries. Arizona, by regulation, requires permits for sewage treatment works and extensions thereof.

All States in the basin may issue rules and regulations pertaining to water pollution abatement, prevention, and control. Hearings are not required before such rules and regulations may be issued.

In California, Colorado, New Mexico, and Wyoming, administrative orders may be issued by the water pollution control authorities relating to pollution abatement and control. In New Mexico, administrative hearings are required to be held in connection with the issuance of such orders, and in California, the regional and State water pollution control

boards are required to hold such hearings, but the State Department of Health is not required to do so.

In all States in the basin except Utah, the water pollution control authorities are given the power to hold hearings in connection with the discharge of their functions. The States in the basin which may hold such hearings are authorized to issue subpoenas in connection therewith, and all but Nevada are specifically given the authority to administer oaths. In addition, California authorizes the payment of witness fees to those answering subpoenas of the State and regional water pollution control boards.

There are no specific exemptions from the water pollution control statutes of the States in the basin. There is, however, a specific provision in the Colorado statute concerning the South Platte River and Bear Creek, which states the "disturbances of water by placer mining or tailings from ore reduction mills flowing into any of said streams or tributaries shall not be construed as defilement or pollution of the waters thereof."

The data in table D indicate that insofar as current information extends, the principal industrial wastes of the Colorado River Basin stem from primary metal mines, mills, and smelters. The food and beverage processing industries form the second greatest source of polluting wastes.

Water is in such short supply that, except in the headwater areas, industry can ill afford to waste it. Large users of water, such as the ore mills, usually reclaim their process water for recycling. Only two coal mines in the basin are known to clean their product hydraulically, all others use dry methods. Most industries, other than the mines and sawmills directly exploiting raw materials, have concentrated within communities served by public sewers. In many instances, however, the industries have not connected with the public system or, where connections have been made, the industrial loading has overloaded the existing sewage treatment facilities.

Table E summarizes available data concerning the adequacy of design and operation of the waste treatment facilities in the Colorado Basin.

This table emphasizes the need for corrective measures at almost one-half of the present sewage treatment plants. It further emphasizes, as does table D, the scant amount of available information concerning industrial wastes and the treatment being provided.

The overloading of many sewage treatment plants and the unsatisfactory design and operation of others precludes even a reasonably accurate quantitative estimate of the pollution kept from the surface waters of the basin by the waste treatment plants. The State water pollution control agencies are intensifying their efforts to improve the operation of sewage treatment works and to obtain additional facilities where needed. Pollution of underground water supplies is a particular concern of the State pollution control agencies in the more arid sections of the basin. Extensive irrigation has increased the mineral content of ground water through concentration of the minerals by evaporation and the leaching of salts from the soil by irrigation water percolating through it. It is reported that several ground-water sources can no longer be used because of this increased mineral content.

Soil conservation projects are operating in some parts of the basin and similar projects are being developed in others. No data are available concerning the quantity of silt kept from the streams by soil conservation projects. Because of the great quantities of silt developing from natural sources which are controllable only at tremendous expense, if at all, the effect of current soil conservation practices is not readily apparent by visual inspection of the flowing waters of the Colorado Basin.

Table F indicates the excellent progress that has been made in the abatement of pollution from sewage wastes during the past four years. The population served by the plants constructed during this period increased from only 500 in 1946 to over 265,000 in 1949. Construction in 1947 provided facilities for five times as many people as did that of 1946. This was increased to seven times by the 1948 construction, while in 1949 treatment facilities were provided for fifteen times as many people as were provided for by the 1948 construction program.

Table D. Existing treatment facilities, industrial*

Type industry	Number of plants	Number of industrial plants having:		
		Treatment facilities	No treatment facilities	Undetermined facilities
Food and allied.....	81	14	43	32
Chemical and allied.....	5	2	3	--
Petroleum and coal.....	45	4	--	41
Primary metals.....	194	9	--	185
Other mining industry.....	4	2	--	2
Miscellaneous.....	1	0	1	0
Total	330	31	47	252

*Industries having separate outlets and discharging wastes directly to watercourse.

Table E. Adequacy of existing treatment facilities

Existing treatment facilities	Number	Adequacy with relation to:					
		Capacity			Operation		
		Satis-factory	Unsatis-factory	Unde-termined	Satis-factory	Unsatis-factory	Unde-termined
Municipal	160	75	84	1	83	62	15
Industrial	31	15	6	10	15	6	10

Table F. Progress in pollution abatement

Year	Municipal		Industrial	
	Plants completed	Design population	Plants completed	Amount of waste treated (in terms of equivalent number of people)
1946	1	500	0	--
1947	2	2,350	0	--
1948	2	17,250	0	--
1949	9	265,160	0	--

POLLUTION PREVENTION MEASURES REQUIRED

The State pollution control agencies are well aware of the need for a more thorough evaluation of the water pollution problem and for the planning and development of a comprehensive program of pollution abatement. To the limit of their resources, the State agencies are attempting to fill in the information gaps, to improve operation of existing treatment facilities, and to secure the treatment facilities required for both municipal and industrial wastes.

The regulatory agencies lack sufficient personnel and funds to administer effectively a comprehensive program of pollution abatement. Present State technical staffs for survey and investigational work and monies for control purposes are so limited that the development of a comprehensive pollution control program is materially handicapped. Sufficient personnel and funds to carry out an effective abatement program are needed by the regulatory agencies so they can proceed with corrective measures before major damages occur.

The State agencies also lack funds for public information programs, which are a prerequisite to a comprehensive pollution control program. It is essential that the general public be kept fully cognizant of the potential effects that increased population or industrialization might have upon the extremely limited water supplies of the region. Pollution abatement and prevention, which will be brought about only by an enlightened public and with the full cooperation of industry, are extremely important, for the future of the Colorado Basin rests upon the assurance of suitable water.

Although the Colorado River Basin has made considerable progress in providing municipal sewage collection and treatment facilities, much additional plant construction and reconditioning is needed before all waters of the basin will be free from the effects of municipal sewage pollution.

It is estimated that sewage treatment projects are needed at 118 communities, if the sewage discharged in the basin is to receive the treatment recommended as necessary by the State pollution control agencies. As shown in table G, these project requirements include 34 new sewage treatment plants, the replacement of 53 obsolete plants, and additional or enlarged facilities at 31 plants.

Of these 118 municipal project requirements, one will serve a population over 14,000, eleven will serve populations between 5,000 and 10,000, and forty-two will serve between 1,000 and 5,000. Sixty-four of the required projects serve populations of under a thousand, forty-four of which are to serve population under 500.

The present (July 1950) construction cost of the recommended municipal sewage treatment facilities is estimated at $11,000,000. This estimate does not include operation and maintenance and covers only capital expenditure for municipal treatment plant facilities. Many major cost items such as lands, rights-of-way, piling, intercepting sewers, etc., which are dependent on local conditions were also omitted from the estimate.

Recognizing that these expenditures will take place over a number of years, the estimated costs will be increased due to added factors. These include additional annual obsolescence and rehabilitation requirements, needs of communities installing new sewer systems, normal population increases and industrial expansion, as well as allowance for presently undetermined needs.

Available information on the present status of industrial waste pollution of the Colorado Basin is so incomplete that it is impossible to evaluate the problem either in terms of the quantity of pollution entering the waters of the basin from the 330 known sources or of the treatment facilities required for its control. It is presently known, however, that 14 of these industrial waste sources require new waste treatment plants, two require additions or enlargements to existing facilities and four require replacement of existing facilities.

An accurate picture of the water pollution problems of the Colorado River Basin depends upon a more complete inventory of all industrial plants, including the amount and the character of their wastes. Also, more complete information is needed upon the efficacy of industrial waste treatment methods now in use, the quantity of polluting substances actually reaching the waters after treatment and the effects of the treated effluents upon both the surface and ground waters of the basin. A compilation of full information on the industrial wastes produced in the basin is a prerequisite to any specific recommendations for the effective control of pollution from industrial sources. The data available are not sufficient to allow for any estimate of the cost of presently known requirements for industrial waste treatment.

Table G. Requirements for municipal and industrial waste treatment plants*

Requirements**	Municipal		Industrial
	Number	Population served by facilities	Number
New plant	34	58,441***	14
Enlargement or additions to existing plant	30	69,826	2
Replace existing plant	54	87,916	4
No project required	75	377,054	12
Undetermined	1	200	298

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

**For individual project needs refer to table I contained in each of the sub-basin discussions which follow Part I of this report.

***One community has a non-sewered population not included in this total, estimated at 5,400 which the State pollution control agency recommends be connected to the new sewage treatment plant.

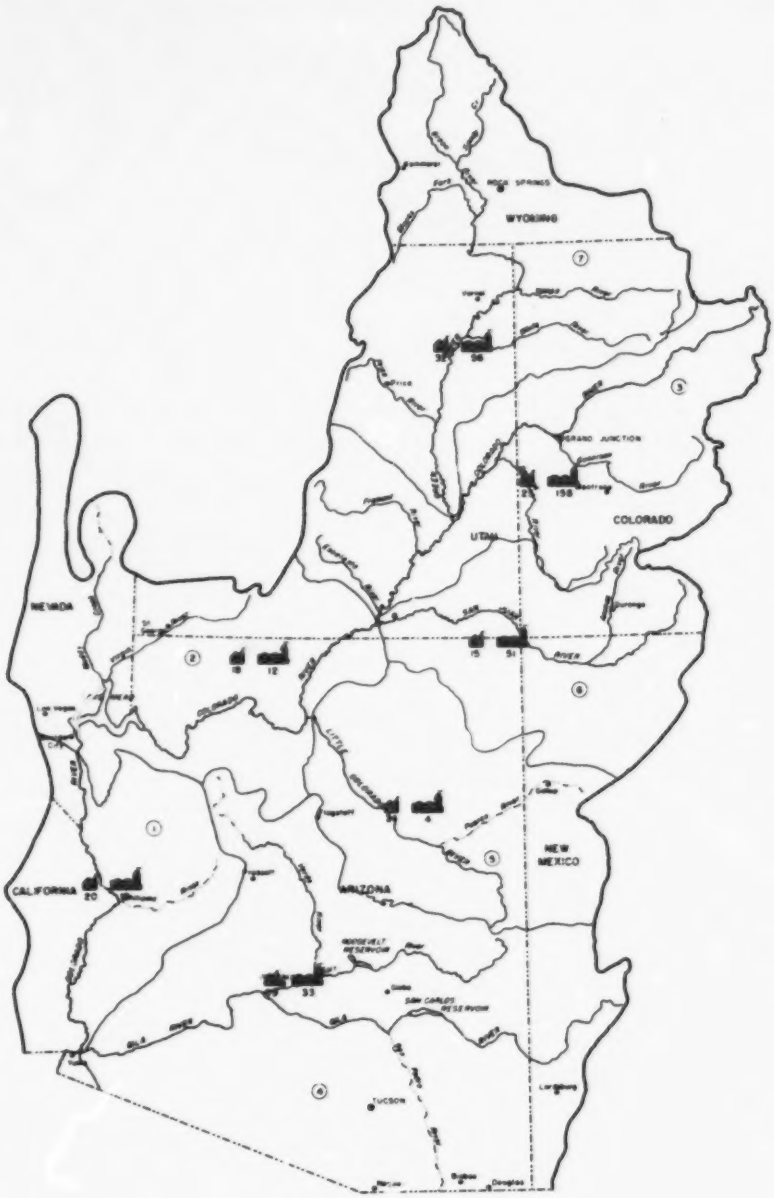
Note: There are also 64 communities in the basin with a combined population of 163,000 for which the State pollution control agencies recommend both sewers and sewage treatment facilities, although the municipal wastes are not now discharged directly to watercourses.

Table H indicates the current status of treatment works projects. Of the 118 needed municipal projects four are under construction, one is awaiting financing, and final plans have been approved for another. No formal action has been taken on the remainder. No formal action has been taken on the 20 industrial waste treatment projects presently known to be needed.

A comprehensive program of water pollution control is needed to abate existing pollution and to prevent additional future pollution of the limited--but vital--water resources of the Colorado River Basin.

Table H. Status of treatment works project to abate pollution, July 1, 1950

Status of project	Number	
	Municipal	Industrial
No formal action	112	20
Abatement ordered	--	--
Plans under preparation	--	--
Final plans approved	1	--
Construction awaiting financing	1	--
Under construction	4	--
Status undetermined	--	--



SUB-BASIN INDEX

① Colorado River Basin, Main Stem, from Gulf to Hoover Dam
② Colorado River Basin, Main Stem, from Hoover Dam to Havasu Crossing
③ Colorado River Basin, Main Stem, above Havasu Crossing
④ Gila River Basin
⑤ Little Colorado River Basin
⑥ San Juan River Basin
⑦ Green River Basin

NUMBER OF MUNICIPAL SOURCES

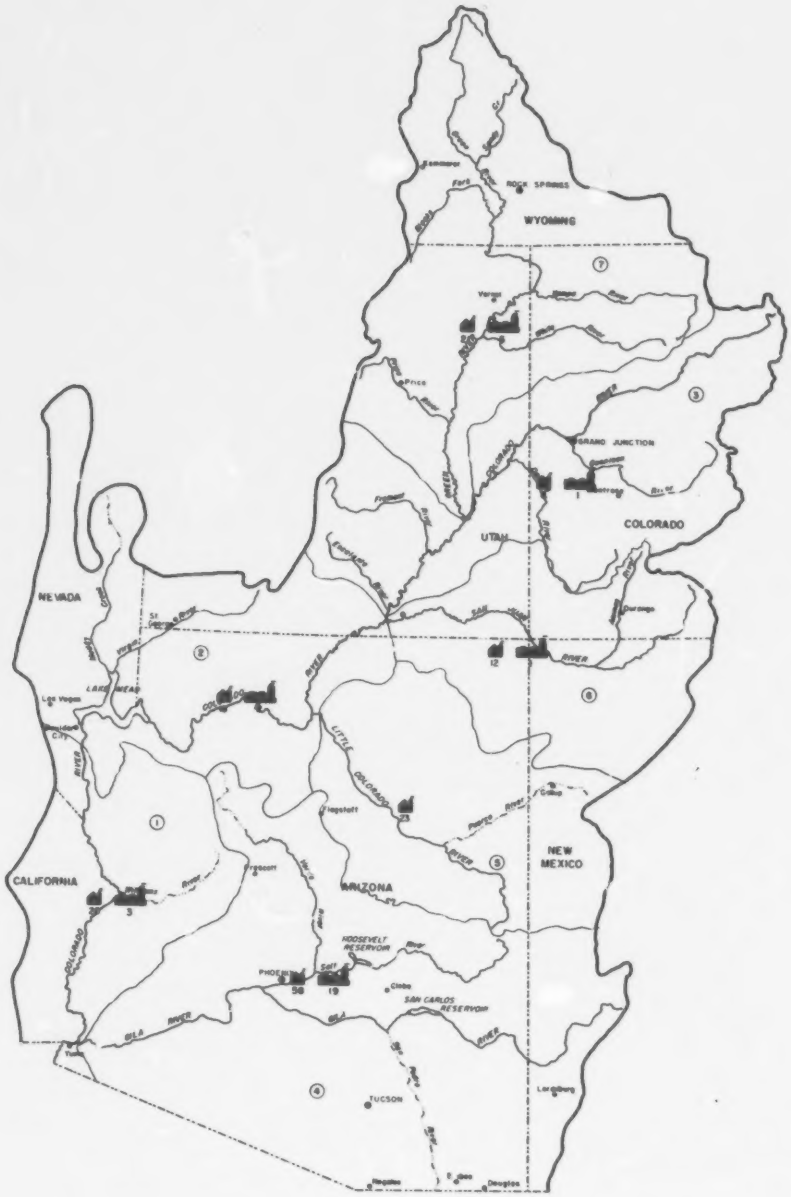
NUMBER OF INDUSTRIAL SOURCES

SCALE OF MILES
40 20 0 20 40 60 80

14-a

COLORADO DRAINAGE BASINS
SOURCES OF POLLUTION
FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL
MAP NO. 1

204715 O - 53 - 4



SUB-BASIN INDEX

(1) Colorado River Basin, Main Stem, from Gulf to Hoover Dam
(2) Colorado River Basin, Main Stem, from Hoover Dam to Hoils Crossing
(3) Colorado River Basin, Main Stem, above Hoils Crossing
(4) Gila River Basin
(5) Little Colorado River Basin
(6) San Juan River Basin
(7) Green River Basin

NUMBER OF EXISTING MUNICIPAL TREATMENT WORKS

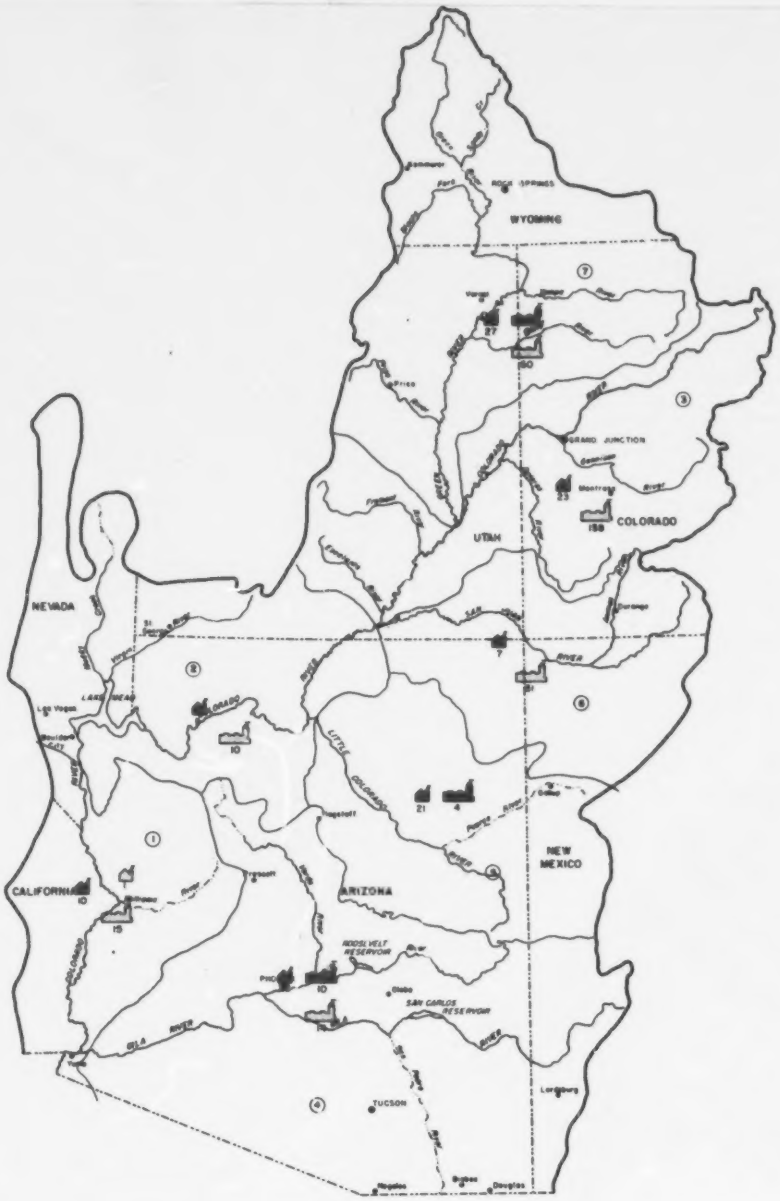
NUMBER OF EXISTING INDUSTRIAL TREATMENT WORKS

SCALE OF MILES

40 20 0 20 40 60 80

-14-

COLORADO DRAINAGE BASINS
EXISTING TREATMENT WORKS
FEDERAL SECURITY AGENCY
Public Health Service
DIVISION OF WATER POLLUTION CONTROL
MAP NO. 2



SUB-BASIN INDEX

1. Colorado River Basin, Main Stem, from Gulf to Hoover Dam
2. Colorado River Basin, Main Stem, from Hoover Dam to Hallo Crossing
3. Colorado River Basin, Main Stem above Hallo Crossing
4. Gila River Basin
5. Little Colorado River Basin
6. San Juan River Basin
7. Green River Basin

NUMBER OF MUNICIPAL PROJECTS REQUIRED

NUMBER OF MUNICIPALITIES WITH PROJECT REQUIREMENTS UNDETERMINED

NUMBER OF INDUSTRIAL PROJECTS REQUIRED

NUMBER OF INDUSTRIES WITH PROJECT REQUIREMENTS UNDETERMINED

SCALE OF MILES

40 20 0 20 40 60 80

-14-C

COLORADO DRAINAGE BASINS

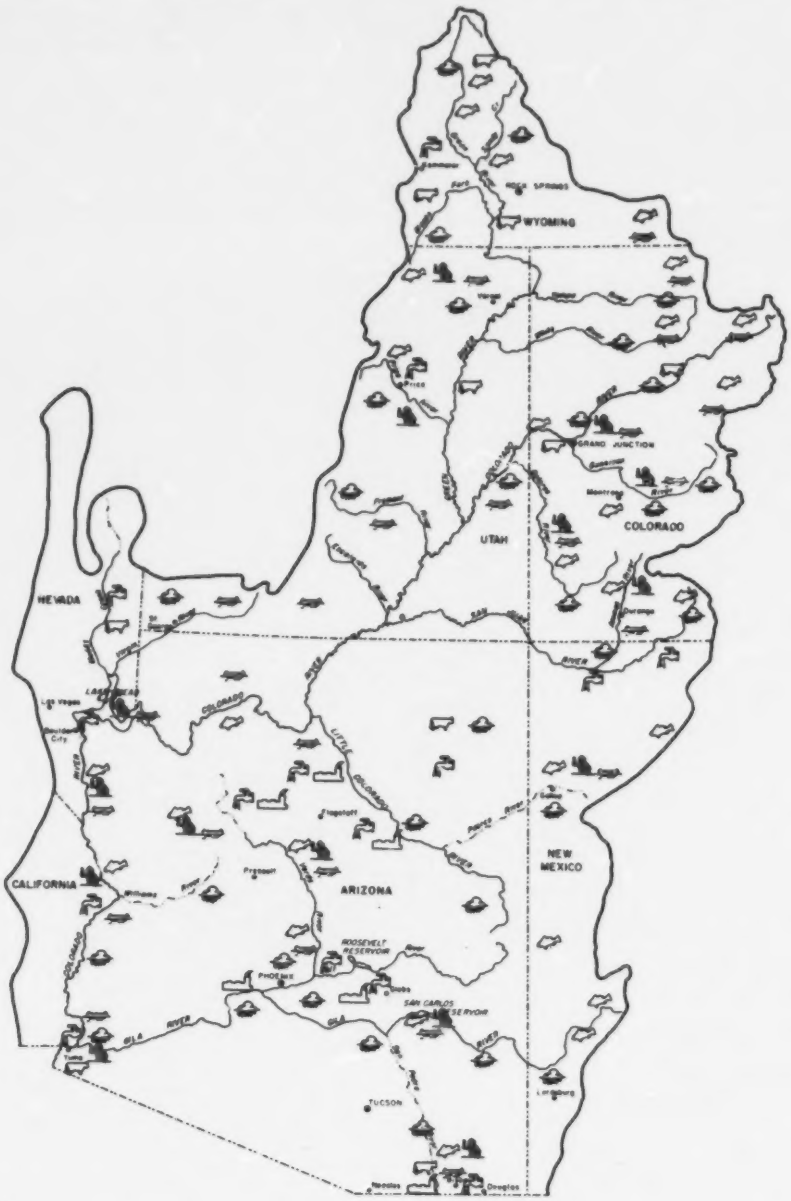
PROJECTS REQUIRED

FEDERAL SECURITY AGENCY

Public Health Service

DIVISION OF WATER POLLUTION CONTROL

MAP No. 3



DOMESTIC WATER SUPPLY

INDUSTRIAL WATER SUPPLY

LIVESTOCK

IRRIGATION

GAME FISHING

BATHING WATER

OTHER RECREATION

SCALE OF MILES

40 30 20 10 0 10 20 30 40 50 60

-14-d

COLORADO DRAINAGE BASINS

EXISTING PRIMARY WATER USES

FEDERAL SECURITY AGENCY

Public Health Service

DIVISION OF WATER POLLUTION CONTROL

MAP NO. 4

SUB-BASIN REPORTS

LOWER COLORADO RIVER SUB-BASIN

The Lower Colorado River Sub-Basin for the purposes of this report consists of a triangular shaped area of approximately 21,750 square miles which extends from an apex at the International border at River Mile 112 to a base at Hoover Dam 435 miles upstream. Flanked by the Providence and the Chocolate Mountains to the west and the Santa Maria, Harcuvar, and Kofa Mountains to the east, the entire sub-basin is one vast barren high desert except for the relatively small areas to which man has supplied water. The Colorado Desert is even more forbidding in many ways than is the better known Death Valley of California.

Average annual precipitation within various sections of the sub-basin ranges from less than five, to not more than ten, inches. Parker, Ariz., in the southern part of the sub-basin, has recorded air temperatures ranging from 9° F. to 127° F. and the annual precipitation averages 3.6 inches. In the northern section of the sub-basin, Needles, Calif., has recorded air temperatures ranging between 18° F. and 125° F. and the annual precipitation there averages 4.6 inches. The arid character of the Lower Colorado River Sub-Basin is exemplified by the facts that the only permanent streams within the entire sub-basin--which is comparable in area to the State of West Virginia--are the main-stem Colorado and the Bill Williams Rivers. The latter stream constitutes the only tributary to the Colorado within the sub-basin limits and it normally contributes but 10 to 15 second-feet. The sub-basin comprises one of the few areas of the country where the inflow of water materially exceeds the outflow. The natural losses of water under virgin conditions is estimated to have been in the order of 1-million acre-feet annually. Under irrigation, water losses currently are of greater magnitude.

The Lower Colorado River Sub-Basin also is unique in that all water is under the complete control of man and is parcelled out in strict accordance with irrigation, municipal, and hydroelectric power demands. Hoover Dam, the upstream limit of the sub-basin, is the largest impoundment on earth and has a reservoir capacity of 32.4-million acre-feet--or sufficient to hold the average flow of the Colorado for two years. In addition to impounding water for irrigation, Hoover Dam likewise has hydroelectric generators with an installed capacity of 1.03-million kilowatts. Hoover Dam forms the initial unit of the Colorado River Project that ultimately will irrigate about 2-million acres of land all of which, at one time, was desert wasteland.

Sixty-seven miles below Hoover Dam, Davis Dam, now under construction, will serve to regulate the surges produced at Hoover Dam and, in addition, will generate 225,000 kilowatts for the power transmission grid which serves much of southern California and western Arizona.

Parker Dam, 88 miles below the Davis Dam site, is the diversion dam for the Colorado River Aqueduct and also provides downstream protection against the occasional flash floods from waters of the Bill Williams River and generates 120,000 kilowatts of hydroelectric

Table A_1. Sources of pollution, municipal

Municipalities*	Sources of pollution (in number of municipalities)	Population served by sewerage system	Amount of pollution discharged to watercourse (in terms of equivalent number of people)**
Having data on pollution load discharged to watercourse	3	4,540	2,915
Having population data available (Data on pollution load to watercourse incomplete or not available)	17	28,566	Not applicable
Total	20	33,106	--

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

**Includes industrial wastes discharged into municipal sewerage systems.

power. The 242-mile Colorado River Aqueduct, constructed by the Metropolitan Water District of Southern California, diverts about 600 second-feet of water pumped from the Parker Dam Reservoir. This serves a combined population estimated in excess of 3-million in 13 southern California communities with water for domestic and industrial purposes.

Below Parker Dam, the Headgate Rock Diversion Dam supplies water for the irrigation of 9,400 acres (ultimately 100,000 acres) mostly on the lands of the Colorado River Indian Agency.

Below Headgate Rock Dam is the 47-foot Imperial Dam and control works for the 90-mile All American Canal that supplies 15,000 second-feet of water for irrigating 400,000 acres in the famed Imperial Valley of Southern California as well as water for the Gila Project of south-western Arizona.

Four miles below Imperial Dam is located Laguna Dam, headworks for the North Valley unit of the Gila project.

The Republic of Mexico, by treaty, has rights to a minimum of 1.5-million acre-feet of Colorado River water annually.

It is readily apparent from the foregoing that irrigation is the dominant water use in the Lower Colorado River Sub-Basin. Davis Dam and Yuma, Ariz. and Yuma Air Base are the only communities within the sub-basin using surface sources (main-stem Colorado River) for domestic purposes.

The economy of the sub-basin rests principally upon agriculture and mining and their associated industries. The warm climate permits both summer and winter cropping, where irrigation water is available, for the production tion of high value crops such as citrus fruits and off-season vegetables. Tourist service also is an important industry of the sub-basin.

Table B_1. Sources of pollution, industrial*

Industries	Sources of pollution (in number of plants)	Amount of pollution discharged to watercourse (in terms of equivalent number of people)
Producing organic wastes	--	--
Producing organic wastes	14	Undetermined
Producing inorganic wastes	2	Not applicable
Producing wastes of undetermined type	0	--
Total	16	--

*Industries having separate outlets and discharging directly to watercourse.

Table C_1.
Existing treatment facilities, municipal

Degree of treatment provided	Number		Population served
	Municipalities*	Plants	
Primary	4	4	5,840
Secondary	15	16	20,666
No treatment	1	--	6,600

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

Gold, lead, copper, silver, zinc, iron, gypsum, vermiculite, manganese, mercury, antimony, tungsten, and uranium comprise the most important mineral resources of the sub-basin. Of these, copper, gold, zinc, silver, and lead are the principal minerals worked at the present time. Most of the currently active mining operations are located in Arizona, principally along Burro Creek, a tributary of the Bill Williams River.

Generally speaking, the waters of the Lower Colorado River are reported of satisfactory quality, insofar as man-made pollution is concerned, to meet adequately all current uses. They are regarded with suspicion, however, for either drinking or bathing purposes in the vicinity of the outfalls of certain main-stem communities which either lack--or have inadequate--sewage treatment facilities. In addition, certain tributaries of Burro Creek are reported to be locally polluted by tailings pond spills.

The natural pollutants of mineral salt and silt are present in the Lower Colorado River water in varying degree. Prior to impoundment of the river by Hoover Dam, the mineral salt content of the river water varied more or less inversely with the river stages. Since the reservoir has filled, however, the dissolved mineral content of water discharged from Hoover Dam is fairly constant and averages 680 parts per million. This increases to 700 parts per million by the time the water reaches Yuma. The dissolved mineral content of the water is, however, well within the upper limits usually accepted for either domestic or agricultural uses.

The water discharged from Hoover Dam is virtually silt-free at all times, although the river accumulates another silt burden, estimated at 13-million tons annually, by the

time it reaches Yuma. This represents an enormous reduction from the 180-million tons of silt annually that the river is estimated to have carried at this point prior to construction of the main-stem dams.

The elimination of the main-stem silt load and the reduction in water temperatures as a result of the depth at which releases are effected completely changed the environmental picture over 30 miles of river following completion of Hoover Dam. As a consequence, a rainbow trout sports fishery has been created in the heart of the Colorado Desert. Upon completion of Davis Dam, and the accompanying warming of the river water this unique fishery may disappear.

All but one of the 20 municipalities of this sub-basin provide sewage treatment. However, to improve the condition of the waters of the sub-basin some of these plants must be replaced or enlarged as they can no longer handle the loads imposed upon them. It is estimated that one new treatment plant is needed, two existing plants must be enlarged and seven others must be replaced. The estimated cost of these facilities, exclusive of operation, maintenance, land, sewers and other variables, is about $1,430,000.

Sixteen industries are known to be discharging wastes directly to the watercourses. Three of these provide waste treatment facilities one of which is known to be adequate, while the remaining two facilities are undetermined as to adequacy of capacity. At the remaining 13 industries no determination has been made as to whether or not treatment facilities have been provided or as to the measures necessary, if any, to abate pollution.

Table D_1. Existing treatment facilities, industrial*

Type industry	Number of plants	Number of industrial plants having:		
		Treatment facilities	No treatment facilities	Undetermined facilities
Food and allied.....	13	--	--	13
Chemical and allied.....	1	1	0	0
Primary metals industry...	2	2	0	0
Total.....	16	3	--	13

*Industries having separate outlets and discharging wastes directly to watercourse.

Table E_1. Adequacy of existing treatment facilities

Existing treatment facilities	Number	Adequacy with relation to:					
		Capacity			Operation		
		Satisfactory	Unsatisfactory	Undetermined	Satisfactory	Unsatisfactory	Undetermined
Municipal	20	10	9	1	12	8	0
Industrial	3	1	--	2	1	--	2

Table F_1. Progress in pollution abatement

Year	Municipal		Industrial	
	Plants completed	Design population	Plants completed	Amount of waste treated (in terms of equivalent number of people)
1946	1	500	0	--
1947	1	350	0	--
1948	0	--	0	--
1949	0	--	0	--

Table G_1 Requirements for municipal and industrial waste treatment plants*

Requirements	Municipal		Industrial
	Number	Population served by facilities	Number
New plant	1	6,600**	--
Enlargement or additions to existing plant	2	1,660	--
Replace existing plant	7	14,846	--
No project required	10	9,800	1
Undetermined	1	200	15

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

**This community has in addition a non-sewered population estimated at 5,400 which the State pollution control agency recommends be connected to the new sewage treatment plant.

Table H_1. Status of treatment works project to abate pollution, July 1, 1950

Status of project	Number	
	Municipal	Industrial
No formal action	7	--
Abatement ordered	--	--
Plans under preparation	--	--
Final plans approved	1	--
Construction awaiting financing	--	--
Under construction	2*	--
Status undetermined	--	--

*Construction of one planned for September, 1950.

Table I_1. Project list - municipalities and industries requiring improvements for abatement of pollution*, July 1, 1950

Name	Population served	Project requirements	Remarks
ARIZONA			
Municipalities:			
Bagdad.....	750	Replace plant	Should serve estimated 1,500 persons
Davis Dam.....	360	Enlarge plant	--
Hilltop.....	1,300	Enlarge plant	--
Kingman.....	4,000	Replace plant	--
Somerton.....	1,420	Replace plant	Under construction
Yuma.....	6,600	New plant	Should serve estimated 12,000 persons
Parker Dam Camp.....	250	Replace plant	--
Private Camp (Ariz.) A**	8,430	Replace plant	--
B**.....		Replace plant	--

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

**The two California communities listed have been coded in deference to the State pollution control law that does not permit pre-judging abatement requirements. The population served by the projects coded is not given as individual listing would identify the communities in question.

NOTE: The Arizona State Department of Health reports many communities and suburban developments that may pollute both ground and surface waters but are not included in this table as they lack communal sewage systems.

MIDDLE COLORADO RIVER SUB-BASIN

The Middle Colorado River Sub-Basin includes approximately 35,000 square miles of land distributed over an L-shaped area along the main-stem Colorado from Hoover Dam, at River Mile 435, to Hall's Crossing 41 miles above the confluence of the San Juan River. The angle of the L is at Hoover Dam, with one arm extending generally northward along the Las Vegas, Muddy, Kanab and Virgin River valleys and the other--and longer arm--lying generally eastward for 400 miles along the main-stem Colorado River. The larger tributaries entering the Colorado within the sub-basin include Kaibibo Wash, Kanab Creek, and the San Juan, Little Colorado, Paria, Muddy, and Virgin Rivers. All but the upper reaches of Kanab Creek and the Muddy and Virgin Rivers flow through canyons so deep that the waters are virtually inaccessible. As a consequence, practically all development within the Middle Colorado River Sub-Basin has been limited to these areas where the surface water could be reached and to the Las Vegas Valley where artesian sources have been exploited.

The Colorado, San Juan, and Little Colorado Rivers all enter the sub-basin in canyons cut 1,500 feet into the surrounding desert plateau. The plateau, deeply scored by intermittent streams that flow but once in several years, comprises much of the sub-basin and it extends from the rugged escarpments of the higher Paunsaugunt Plateau of southern Utah with a general southerly slope to the rugged San Francisco Mountains of Arizona. Much of this plateau is forested with pinyon, juniper and ponderosa pine, but a large portion is a formidable arid wasteland where vegetation is sparse to non-existent and where animal life can exist only at the higher elevations or in proximity to the scattered springs and seepage holes that exist. Through the middle of this plateau, the river flows through the world-famous Grand Canyon of the Colorado--4 to 18 miles wide and 5,000 to 6,000 feet below the rim--eventually reaching the reservoir behind Hoover Dam.

The Middle Colorado River Sub-Basin is extremely arid, the average annual rainfall exceeding six to eight inches only in the higher portions of the sub-basin. The only streams originating within the sub-basin that are not intermittent in character are the spring-fed Muddy and Virgin Rivers.

The Middle Colorado River Sub-Basin is one of the most sparsely settled areas of the United States, presumably because permanent waters are so limited or so inaccessible. Including the urban inhabitants, the population density for the sub-basin averages approximately one person for every two square miles of land.

The upper Muddy, the Virgin, and the Kanab River valleys are more adaptable to irrigation and development has occurred to the limit of available water. Within these valleys some 36,000 acres of land are under irrigation, primarily for the production of beef and dairy cattle and feed crops. About 1,200 acres near Las Vegas, Nev., are irrigated from underground water sources.

The spectacular erosion phenomena and fishing and hunting afforded at Lake Mead, and in the Kaibab country particularly, attract to the region tourists and recreation seekers in great numbers. This tourist trade comprises the principal industry of the area. Other industries in the sub-basin include grazing, lumbering, and mining.

About one-half of the sub-basin area lies within the Federally owned or controlled Navajo, Kaibab, and Hualpai Indian Reservations; Zion, Bryce Canyon, Grand Canyon National Monument and Grand Canyon National Parks, and Lake Mead National Recreational Area. Pollution abatement within these areas fall within the responsibilities of the Federal Office of Indian Affairs or the National Park Service.

Man-made water pollution problems in the Middle Colorado Sub-Basin, as reported by the State pollution control agencies, are minor and are centered principally in the populated areas of the Muddy, Kanab, and Virgin River valleys. These problems are local in scope and involve use of the water for irrigation. Only the tributary waters are affected, since there are no communities within ten miles of the main-stem Colorado in this sub-basin.

At the South Rim of the Grand Canyon one of the pioneer developments in municipal waste treatment has been in operation for the past 20 years. The entire sewage flow from the community of Grand Canyon, Ariz., and its associated service and tourist accommodations is utilized to produce an industrial water supply of a high degree of purity. This installation, which employs standard methods of sewage and water treatment practices, has proven to be economically successful because of the extreme scarcity and resultant high cost of water in this area.

Water pollution from natural sources is, on the other hand, exceptionally severe. The

main-stem Colorado, as well as the lower reaches of all tributaries, are extremely turbid as evidenced by the estimated 199-million tons of silt deposited annually in Lake Mead. Mineral springs in the lower Virgin River valley render the water unsuitable for domestic purposes and unfit for irrigating other than salt resistant crops.

Only three communities in the sub-basin utilize surface waters for domestic purposes. Williams, Ariz., serves 3,500 consumers with water from a lake high on Mount Williams. Boulder City, Nev., draws water from Lake Mead to serve 2,500 consumers, and Overton, Nev., serves 500 consumers with water from the Muddy River.

The industries discharging untreated wastes into waters of the sub-basin include a few small slaughterhouses (averaging 10 to 50 beeves per month) and milk processing plants (up to 80 gallons of milk per day). In most instances the wastes from these plants are discharged into irrigation ditches. In only one instance have industrial waste pollution complaints been registered. These concern a slaughterhouse which discharges untreated liquid wastes into an irrigation ditch that flows through the city of Kanab, Utah shortly after receiving these wastes.

There are no reported instances wherein man-made pollution has restricted any current use of water within the Middle Colorado River Sub-Basin. It is estimated, however, that adequate treatment of the sub-basin's municipal sewage will require the replacement of three existing plants and the enlargement of two others. The extent of industrial waste treatment needs is undetermined at present. The estimated cost for capital expenditures for sewage treatment facilities, exclusive of land, sewers, operation or maintenance, is approximately $412,000.

Table A_2. Sources of pollution, municipal

Municipalities*	Sources of pollution (in number of municipalities)	Population served by sewerage system	Amount of pollution discharged to watercourse (in terms of equivalent number of people)**
Having data on pollution load discharged to watercourse	0	--	--
Having population data available (Data on pollution load to watercourse incomplete or not available)	18	52,995	Not applicable
Total	18	52,995	--

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

**Includes industrial wastes discharged into municipal sewerage systems.

Table B_2. Sources of pollution, industrial*

Industries	Sources of pollution (in number of plants)	Amount of pollution discharged to watercourse (in terms of equivalent number of people)
Producing organic wastes	8	31
Producing organic wastes	1	Undetermined
Producing inorganic wastes	3	Not applicable
Producing wastes of undetermined type	0	Undetermined
Total	12	--

*Industries having separate outlets and discharging wastes directly to watercourse.

Table C_2.
Existing treatment facilities, municipal*

Degree of treatment provided	Number		Population served
	Municipalities*	Plants	
Primary	4	4	6,015
Secondary	14	14	46,980
No treatment	0	--	--

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

Table D_2. Existing treatment facilities, industrial*

Type industry	Number of plants	Number of industrial plants having:		
		Treatment facilities	No treatment facilities	Undetermined facilities
Food and allied.....	8	0	8	0
Other mining industry.....	3	2	--	1
Miscellaneous (Laundry)...	1	0	1	0
Totals.....	12	2	9	1

*Industries having separate outlets and discharging wastes directly to watercourse.

Table E_2. Adequacy of existing treatment facilities

Existing treatment facilities	Number	Adequacy with relation to:					
		Capacity			Operation		
		Satisfactory	Unsatisfactory	Undetermined	Satisfactory	Unsatisfactory	Undetermined
Municipal	18	13	5	0	13	5	0
Industrial	2	2	0	0	2	0	0

Table F_2. Progress in pollution abatement

Year	Municipal		Industrial	
	Plants completed	Design population	Plants completed	Amount of waste treated (in terms of equivalent number of people)
1946	0	--	0	--
1947	0	--	0	--
1948	0	--	0	--
1949	0	--	0	--

Table G_2. Requirements for municipal and industrial waste treatment plants*

Requirements	Municipal		Industrial
	Number	Population served by facilities	Number
New plant	0	--	--
Enlargement or additions to existing plant	2	5,268	--
Replace existing plant	3	4,615	--
No project required	13	43,112	2
Undetermined	0	--	10

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

Note: There are also 4 communities in this sub-basin, with a combined population estimated at 5,200, for which state pollution control agencies recommend both sewers and sewage treatment facilities although the municipal wastes are not discharged directly to watercourses.

Table H_2. Status of treatment works project to abate pollution, July 1, 1950

Status of project	Number	
	Municipal	Industrial
No formal action	5	--
Abatement ordered	--	--
Plans under preparation	--	--
Final plans approved	--	--
Construction awaiting financing	--	--
Under construction	--	--
Status undetermined	--	--

Table I_2. Project list - municipalities and industries requiring improvements for abatement of pollution*, July 1, 1950

Name	Population served	Project requirements	Remarks
Municipalities:			
Hurricane, Utah.....	1,268	Enlarge plant	--
Kanab, Utah.....	1,530	Replace plant	--
St. George, Utah.....	3,000	Replace plant	--
Zion National Park, Utah....	0-4,000	Enlarge plant	--
Kaibito, Ariz.(Indian School).....	85	Replace plant	--

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

UPPER COLORADO RIVER (ABOVE HALL'S CROSSING) SUB-BASIN

The Upper Colorado River Sub-Basin, for the purposes of this report is identified as the drainage area of the Colorado River above its confluence with the San Juan River (Hall's Crossing), exclusive of the Green River watershed. The drainage from the Fremont and Escalante Rivers, although entering the Colorado below its juncture with the Green, is included in this sub-basin. The major tributaries to the Colorado are the Gunnison and Dolores Rivers. The Uncompahgre River is a principal tributary to the Gunnison River.

The tributary drainage basins, with the exception of the Fremont and Escalante Rivers, are almost completely surrounded by the towering peaks of the Rocky Mountains and are separated from each other by these mountain monarchs. There are almost two dozen peaks bordering or in this drainage sub-basin that are over 14,000 feet in elevation and many more in excess of 13,000 feet.

Due to the rugged nature of the terrain, much of this sub-basin is inaccessible, except by pack-horse or mule train. Major highways pass through the sub-basin entering through high mountain passes and descend the river valleys to points of junction with other valleys. With the exception of the mining communities located near points where desirable mineral veins appear, the communities are located in the river valleys beside the highways, with high valley walls on either side. These valley communities depend upon the agriculture which has developed on the bench land where sufficient space is available. The uniform climatic conditions and an abundance of irrigation water has stimulated this development.

The presence of the high mountain peaks has created a unique climatic condition. These peaks deflect low pressure areas, so that sudden changes of climate that usually follow the passing of a low pressure area are not experienced here. Severe cold waves are comparatively rare and high pressure areas tend to form and remain for days and even weeks with attendant clear weather. At lower levels the wind movement is light, common to the mountain and valley type, where the wind moves up the valley in late afternoon, subsides ip early evening, then blows down the valley in the early morning.

Rainfall is highest among the mountain peaks, reaching a maximum of 40 inches annually at some stations. The precipitation decreases with the altitude to an annual average of ten inches near the confluence of the Gunnison and Colorado Rivers. Below this junction point the amount of precipitation further decreases to a minimum annual average of six inches in the area where the Green, the Fremont and the Escalante Rivers join the Colorado.

The precipitous nature of the sub-basin produces rivers that yield their waters rapidly after release on the high peaks. As a result, stream flow may fluctuate within wide limits over short intervals of time. In the upper reaches of the sub-basin the channels have been scoured until they flow through rocky canyons. At the transitional points where the rivers leave the mountain canyons and enter the outfall or piedmont plain, the velocity decreases, but not sufficiently to decrease the silt carrying capacity. Tremendous volumes of silt are picked up and transported by these rivers as they pass through the more friable soils.

A record of flows at the gaging stations closest to the mouth of each stream is presented in the following table:

River**	Station in Colorado	Length of record (Years)	Flow in second-feet (cubic feet per second)		
			Average	Maximum*	Minimum*
Colorado....	Cameo.....	14	4,056	36,000	700
Gunnison....	Grand Junction..	39	2,761	35,700	106
Uncompahgre.	Delta.....	9	1,061	15,400	45
Dolores.....	Gateway.....	10	322	3,730	7

*Extremes of record.
**Records of the discharge of the Fremont and Escalante Rivers are fragmentary and have not been recorded near the mouth of either stream so that contributary characteristics cannot be determined. Both are minor contributors to the total flow of the Colorado River.

By far the major water use is for the irrigation of agricultural lands. There are almost 600,000 acres of land irrigated by waters from the upper Colorado and its tributaries. The water required for irrigation will vary from a few inches to eight feet per year, depending on irrigation practices, rainfall, availability of water, location, crops produced and other factors. It is estimated that approximately 900,000 acre-feet per year are used to irrigate these lands. An additional estimated 519,300 acre-feet per year are exported from the sub-basin to the Rio Grande, South Platte, and Arkansas River Sub-Basins. Most of the water that is exported is used for irrigation purposes.

Because of wide seasonal flow variation, impoundments are vital to insure a dependable year round flow. There are 30 reservoirs, each with capacities of more than 1,000 acre-feet, having a total combined capacity of 550,000 acre-feet. The future development of the river sub-basin includes plans for the construction of four large dams identified as Bridgeport, Dewey, Crystal, and Cottonwood, which will impound 880,000, 8,200,000, 510,000, and 2,500,000 acre-feet respectively. The construction of any of these will have a marked effect on the development of the area and the character of the stream flow of the river. In addition to recreational developments around such impoundments, these dams have varied purposes such as irrigation, silt retention, flood control stream regulation, fish and wildlife conservation.

Within the near future the U.S. Forest Service will sell 4,565,000 cords of timber to a private contractor who plans to install a 200-ton per day pulp mill estimated to cost $20,000,000, at a point on the Colorado River 10 miles west of Glenwood Springs, Colo. This mill will utilize the insect-killed Engelmann Spruce in this drainage sub-basin as well as that in the Green River drainage area. Inasmuch as the plans for this plant are not yet complete, the type of waste treatment to be provided cannot be outlined in this report. The present contract anticipates a 30-year sale and commitment of timber to maintain the industry on a permanent basis.

The 1950 population in this drainage sub-basin is estimated to be 117,000 persons, a population density of 2.5 persons per square mile. There are 51 community water systems which serve an estimated 58,000 people with almost 10,000,000 gallons of water per day. Seventeen percent of the population is served by 17 ground water systems, 15 percent is served by four combined ground and surface water systems, and 68 percent is served by 30 surface water systems.

The surface water pollutional problems in this sparsely settled water shed are not as pronounced as in the more populous river sub-basins. The pollution caused by municipal sewage and manufacturing waste is limited to small areas below communities. Probably the major source of industrial pollution is from the mining mill operations both active and abandoned. These operations have created tailing dumps of extremely finely ground material. With rainfall, and scour from stream flow, these tailings erode into the stream channels. A number of streams are reported to have been ruined for fishing purposes due to the detrimental effects of these tailings. The Uncompahgre River, comparable to the Gunnison River in geographic location but in contrast to the latter in turbidity, is not a fishing stream, due to the presence of these mining wastes. Up to the present time, the full effect of these wastes has not been completely evaluated in available reports.

It is reported by the State water pollution control authorities that there are 17 communities within the sub-basin that require new sewage treatment plants and six others that require quire enlargement, addition to or replacement of existing facilities. The total estimated cost of these improvements is $806,000.

Table A3. Sources of pollution, municipal

Municipalities*	Sources of pollution (in number of municipalities)	Population served by sewerage system	Amount of pollution discharged to watercourse (in terms of equivalent number of people)**
Having data on pollution load discharged to watercourse	0	--	--
Having population data available (Data on pollution load to watercourse incomplete or not available)	25	38,396	Not applicable
Total	25	38,396	--

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

**Includes industrial wastes discharged into municipal sewerage systems.

No determination has been made on the waste waste treatment needs for the 158 industries discharging wastes directly to the watercourses of the sub-basin.

Table B_3. Sources of pollution, industrial*

Industries	Sources of pollution (in number of plants)	Amount of pollution discharged to watercourse (in terms of equivalent number of people)
Producing organic wastes	7	276,348
Producing organic wastes	1	Undetermined
Producing inorganic wastes	1	Not applicable
Producing wastes of undetermined type	149	Undetermined
Total	158	--

*Industries having separate outlets and discharging wastes directly to watercourse.

Table C_3.
Existing treatment facilities, municipal

Degree of treatment provided	Number		Population served
	Municipalities*	Plants	
Primary	7	7	23,755
Secondary	1	1	810
No treatment	17	--	13,831

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

Table D_3. Existing treatment facilities, industrial*

Type industry	Number of plants	Number of industrial plants having:		
		Treatment facilities	No treatment facilities	Undetermined facilities
Food and allied.....	14	--	9	5
Petroleum and coal.....	6	--	--	6
Primary metals industry...	138	1	--	137
Totals.....	158	1	9	148

*Industries having separate outlets and discharging wastes directly to watercourse.

Table E_3. Adequacy of existing treatment facilities

Existing treatment facilities	Number	Adequacy with relation to:					
		Capacity			Operation		
		Satisfactory	Unsatisfactory	Undetermined	Satisfactory	Unsatisfactory	Undetermined
Municipal	8	2	6	0	2	5	1
Industrial	1	--	--	1	--	--	1

Table F_3. Progress in pollution abatement

Year	Municipal		Industrial	
	Plants completed	Design population	Plants completed	Amount of waste treated (in terms of equivalent number of people)
1946	0	--	0	--
1947	0	--	0	--
1948	0	--	0	--
1949	0	--	0	--

Table G_3. Requirements for municipal and industrial waste treatment plants*

Requirements	Municipal		Industrial
	Number	Population served by facilities	Number
New plant	17	13,831	--
Enlargement or additions to existing plant	3	20,550	--
Replace existing plant	3	3,055	--
No project required	2	960	--
Undetermined	0	--	158

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

Note: There are also 14 communities, with an estimated combined population of 8,321 for which State pollution control agencies recommend both sewers and treatment facilities although the municipal wastes are not discharged directly to watercourses.

Table H_3. Status of treatment works project to abate pollution, July 1, 1950

Status of project	Number	
	Municipal	Industrial
No formal action	23	--
Abatement ordered	0	--
Plans under preparation	0	--
Final plans approved	0	--
Construction awaiting financing	0	--
Under construction	0	--
Status undetermined	0	--

Table I$_3$. Project list - municipalities and industries requiring improvements for abatement of pollution*, July 1, 1950

Name	Population served	Project requirements	Remarks
Aspen, Colo.	200	New plant	--
Climax, Colo.	860	New plant	--
Delta, Colo.	3,820	New plant	--
Eagle, Colo.	518	New plant	--
Fruita, Colo.	1,000	New plant	--
Glenwood Springs, Colo.	2,550	Enlarge plant	--
Grand Junction, Colo.	14,250	Enlarge plant	--
Gunnison, Colo.	1,850	New plant	--
Hotchkiss, Colo.	653	New plant	--
Montrose, Colo.	3,750	Enlarge plant	--
Olathe, Colo.	700	New plant	--
Ouray, Colo.	600	New plant	--
Palisade, Colo.	855	Replace plant	--
Paonia, Colo.	1,100	New plant	--
Rifle, Colo.	1,500	Replace plant	--
Telluride, Colo.	1,340	New plant	--
Uravan, Colo.	400	New plant	--
Moab, Utah	700	Replace plant	--
Breckenridge, Colo.	200	New plant	--
De Begue, Colo.	120	New plant	--
Gypsum, Colo.	160	New plant	--
Lake City, Colo.	185	New plant	--
Red Cliff, Colo.	125	New plant	--

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

GILA RIVER SUB-BASIN

The Gila River Sub-Basin forms a rectangular watershed which includes a small portion of southeastern New Mexico as well as virtually all of southern Arizona. For the purposes of this report, several small desiccating basins and two minor drainages discharging into Mexico are included as part of the Gila Sub-Basin. The total area involved is 64,450 square miles, or approximately that covered by all of the New England States.

The Gila River Sub-Basin is rimmed by high mountains except for the western slope. Elevations within the sub-basin range from 12,600 feet at Humphreys Peak near Flagstaff, Ariz., to approximately 100 feet at the confluence of the Gila and the Colorado near Yuma, Ariz.

The Gila River flows for half of its 800-mile course within steep walled canyons alternating with relatively wide flat valleys. Both the canyons and valleys are flanked by mountain ridges rising to elevations of 7,000 to 10,000 feet. The major tributaries joining the Gila in this section are the San Francisco from the northeast and the San Pedro, of Mexican origin, from the south. Near Phoenix, the Gila emerges from the canyons onto a broad desert wasteland of successive wide valleys transected by low mountain ranges. In the lower section, the Gila receives the Santa Cruz River which flows southward into Mexico from the mountains of southern Arizona, then hairpins back northward across a wide desert that absorbs all but the flood flows. The Salt River, the largest tributary of the Gila, rises high in the timbered White Mountains of east central Arizona to be joined by the Verde from the central Arizona plateau and, finally, to meet the Gila in the broad open plains near Phoenix. The lower tributaries of the Gila include the Agua Fria from the timbered Mingus Mountains of central Arizona, and the Hassayampa which heads in the Prescott National Forest of central Arizona.

All streams within the Gila Sub-Basin attain maximum flows during late winter and early spring when the mountain snows are melting. Precipitation occurs mainly in the late winter and late summer with the intervening periods being virtually rain-free. Most of the Gila watershed has an annual rainfall averaging less than ten inches and only in a very few high mountainous areas does the rainfall exceed 20 inches. The evaporation rate is extremely high owing to the prevailing low humidity of the area. The annual evaporation rates in the different parts of the sub-basin vary between 77 and 120 inches which, in association with a rainfall of but three to 20 inches, results in a marked net loss of surface water throughout the sub-basin.

All rivers in the Gila Sub-Basin are unique in that they are subject to such complete control and utilization that water seldom reaches their mouths. As an example, the main-stem Gila twelve miles above its mouth drains an area approximately the size of the State of Michigan, but the river flowed a total of only 420 acre-feet at that point during a six-year period from August, 1941, to October, 1947. The run-off to the river during this same period approximated 1.27 million acre-feet annually.

Surface waters of the Gila and its tributaries carry considerable quantities of dissolved salts, chiefly sodium chloride and the sulphates and bicarbonates of sodium, calcium, and magnesium. Analyses of the low flows of the Gila made at Gillespie Dam, approximately 200 miles from the mouth, show over 6,000 parts per million of total dissolved solids in comparison with flood flows which carry as little as 300 parts per million. Some of the surface water in the smaller tributaries, and much of the ground water, contains fluorides in such high quantities that it is often difficult to obtain satisfactory domestic water supplies.

The quality of the ground water obtained from artesian wells and springs varies widely with location, many sources yielding water unsuited for either domestic use or irrigation. Ground waters of the sub-basin generally are unsuitable for industrial purposes.

The Gila Sub-Basin contains the sunniest area of the United States, the average number of clear days exceeding 240, and in some parts 280, per year. Temperatures are high, over most of the sub-basin readings of 100° F, in the shade occur frequently throughout the long summer which lasts from April to November. The period between the first killing frost in the fall and the last in the spring is short, exceeding three months only in the mountains. In the lower sections of the sub-basin, frost-free periods of several years duration are common.

Average annual air temperatures range from slightly below 50° F. to above 70° F. The extremes recorded at Thatcher, in the upper part of the sub-basin, are 7° F. to 116° F. At Phoenix, in the central section, the extremes of recorded temperatures range from 16° F. to 118° F. and at Mohawk, in the lower basin, from 16° F. to 126° F.

There are no natural lakes of appreciable size in the Gila Sub-Basin. There are, however, nine major impoundments (1945) ranging in capacity from 1.4 million acre-feet and 1.2 million acre-feet for Roosevelt and Coolidge Reservoirs respectively, to 14,000 acre-feet for Clear Creek. These nine impoundments serve in the interests of irrigation, power, and flood control. The total storage capacity of the nine impoundments is 3,407,400 acre-feet.

The population (1950 census) of the Gila Sub-Basin was about 655,500, 39 percent being classified as urban, 18 percent as rural-farm, and 43 percent as rural-non farm. The population is concentrated in areas where irrigation is extensively practiced with lesser concentrations in areas of recreational and scenic attraction.

There are 25 communities in the Gila Sub-Basin serving a total of 155,000 consumers with 20.3 million gallons of ground water daily, and three communities serving 117,500 consumers with 50.6 million gallons of combination surface and ground water daily. In addition, 37 communities serve 78,000 consumers with an unknown quantity of ground water and one community serves 7,000 customers with an unknown quantity of combination surface and ground water. Water consumption estimated from those communities for which data are available, is 260 gallons per capita per day. The large volumes of water used in air conditioning, as well as lawn sprinkling, presumably accounts for the higher than average per capita daily consumption.

Farming and ranching are extensively practiced in the Gila Sub-Basin. Principal agricultural products include cattle, sheep, citrus and other fruits, and truck crops. Without irrigation much of this farming would not be economical. Approximately 750,000 acres of land are under irrigation. Mining and lumbering industries flourish in many parts of the sub-basin adding materially to the income of the inhabitants. The principal minerals mined and processed are copper, zinc, lead, gold and silver. An additional source of revenue is the lucrative tourist trade attracted to the area by the dry sunny climate.

Man-made pollution has not precluded the use of water in most of the Gila Sub-Basin. Water is so scarce that neither its sanitary nor mineral quality receives the concern generally held in less arid regions. In the more populated sections, virtually all surface water is confined to irrigation canals which, in addition to serving their intended function, also are used for swimming, fishing, and in some instances are used for domestic water supply by isolated farmers and field workers.

Although the Arizona State Department of Health requires the effective treatment of all wastes which might reach either surface or underground sources of irrigation or domestic water, they report that man-made pollution, especially chemical pollution of ground water, renders water in the Phoenix area unfit for domestic, irrigation or industrial purposes.

Fifty-eight of the 59 municipalities in the sub-basin have sewage treatment facilities. However many of these are no longer adequate to handle the loads now imposed upon them and require replacement or enlargement. It is estimated that the proper treatment of municipal sewage will require the construction of one new plant, the replacement of 13 and the enlargement of eight others. The estimated cost of these facilities exclusive of operation, maintenance, land, sewers and other items which vary locally is approximately $5,063,000.

Of the 33 sources of industrial pollution discharging wastes directly to the waters, six are known to require new waste treatment plants, and four are known to require replacement of existing facilities. No determination has been made on the waste treatment needs at 14 other sources of industrial pollution.

Table A4. Sources of pollution, municipal

Municipalities*	Sources of pollution (in number of municipalities)	Population served by sewerage system	Amount of pollution discharged to watercourse (in terms of equivalent number of people)**
Having data on pollution load discharged to watercourse	1	120,000	1,460
Having population data available (Data on pollution load to watercourse incomplete or not available)	58	247,743	Not applicable
Total	59	367,743	--

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

**Includes industrial wastes discharged into municipal sewerage systems.

Table B_4. Sources of pollution, industrial*

Industries	Sources of pollution (in number of plants)	Amount of pollution discharged to watercourse (in terms of equivalent number of people)
Producing organic wastes	14	1,962
Producing organic wastes	7	Undetermined
Producing inorganic wastes	10	Not applicable
Producing wastes of undetermined type	2	Undetermined
Total	33	--

*Industries having separate outlets and discharging wastes directly to watercourse.

The remaining nine sources are known not to require any additional treatment measures at this time. Presently available data do not permit an estimate of the cost of required industrial waste treatment facilities.

Table C_4.
Existing treatment facilities, municipal

Degree of treatment provided	Number		Population served
	Municipalities*	Plants	
Primary	15	15	48,665
Secondary	43	43	317,878
No treatment	1	--	1,200

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

Table D_4. Existing treatment facilities, industrial*

Type industry	Number of plants	Number of industrial plants having:		
		Treatment facilities	No treatment facilities	Undetermined facilities
Food and allied.....	21	12	7	2
Chemical and allied.....	4	1	3	0
Primary metals.....	7	6	0	1
Other mining.....	1	--	--	1
Total.....	33	19	10	4

*Industries having separate outlets and discharging wastes directly to watercourse.

Table E_4. Adequacy of existing treatment facilities

Existing treatment facilities	Number	Adequacy with relation to:					
		Capacity			Operation		
		Satisfactory	Unsatisfactory	Undetermined	Satisfactory	Unsatisfactory	Undetermined
Municipal	58	37	21	0	36	10	12
Industrial	19	9	4	6	9	4	6

Table F_4. Progress in pollution abatement

Year	Municipal		Industrial	
	Plants completed	Design population	Plants completed	Amount of waste treated (in terms of equivalent number of people)
1946	0	--	0	--
1947	1	2,000	0	--
1948	2	17,250	0	--
1949	6	258,000	0	--

Table G_4. Requirements for municipal and industrial waste treatment plants*

Requirements	Municipal		Industrial
	Number	Population served by facilities	Number
New plant	1	1,200	6
Enlargement or additions to existing plant	8	23,048	0
Replace existing plant	13	40,803	4
No project required	37	302,692	9
Undetermined	0	--	14

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

There are also 36 communities in this subbasin with a combined population estimated at 142,773, for which State pollution control agencies recommend both sewers and sewage treatment facilities although the municipal wastes are not discharged directly to watercourses.

Table H_4. Status of treatment works project to abate pollution, July 1, 1950

Status of project	Number	
	Municipal	Industrial
No formal action	22	10
Abatement ordered	--	--
Plans under preparation	--	--
Final plans approved	--	--
Construction awaiting financing	--	--
Under construction	2	--
Status undetermined	--	--

Table I4. Project list - municipalities and industries requiring improvements for abatement of pollution*, July 1, 1950

Name	Population served**	Project requirements	Remarks
ARIZONA			
Municipalities:			
Casa Grande	3,844	Replace plant	Plant should serve 4,200
Clifton	4,500	Replace plant	--
Florence	2,700	Replace plant	--
Fort Apache	200	Enlarge plant	--
Glendale	8,174	Replace plant	Heavy industrial load
Globe	6,456	Enlarge plant	--
Hayden	1,000	Enlarge plant	Should serve 1,500
Humboldt	400	Replace plant	--
McNary	800	Replace plant	Should serve 2,500
Mesa	7,000	Enlarge plant	Reported OK 12/15/50
Miami	4,327	Replace plant	--
Pima	826	New plant	--
Prescott	6,934	Replace plant	Should serve 10,000
Sacaton	200	Replace plant	--
Safford	3,762	Enlarge plant	--
Salome	175	Replace plant	--
Sedona Lodge	400	Replace plant	--
Sonora-Ray	2,250	Replace plant	--
Tempe	8,000	Replace plant	Should serve 11,000
Tiger	1,200	New plant	--
Wickenburg	1,730	Enlarge plant	--
White River	200	Enlarge plant	--
Industries:***			
A	1,060	New plant	--
B	--	New plant	--
C	261	New plant	--
D	--	New plant	--
E	--	New plant	--
F	1,875	New plant	--
G	860	New plant	--
H	--	New plant	--
I	800	New plant	--
J	--	Replace plant	--

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

**For industries this figure represents the population equivalent of their wastes.

***The industries listed herein have been coded in deference to the wishes of the Arizona State Health Department.

Note: The Arizona State Department of Health reports many communities and suburban developments that may pollute both ground and surface waters but are not included in this table as they lack communal sewage systems.

LITTLE COLORADO RIVER SUB-BASIN

The Little Colorado River Sub-Basin occupies an ovate section of northeastern Arizona and west-central New Mexico which measures approximately 250 miles in length and 150 miles in width. The area included within the sub-basin amounts to 25,000 square miles, or an area equal to the State of West Virginia. Four fifths of the sub-basin lies within the State of Arizona. The sub-basin is characterized by high forested mountain ridges giving way to vast, gently sloping, barren plains broken by isolated mesas and volcanic plugs and these, in turn, to deserts and arid wastelands.

The extremes of altitude found within the sub-basin range from the 12,611-foot Humphreys Peak in the San Francisco Mountains near Flagstaff, Ariz., to slightly over 4,000 feet where the Little Colorado and Colorado Rivers join.

The average temperatures over the sub-basin vary more or less inversely with the elevation, the extremes recorded being 46° F. at Flagstaff and 55° F. at Tuba City, Ariz. The range of maximum temperatures varies from 98° F. recorded at Gallup, N. M., to 110° F. at Tuba City, Ariz., and minimum temperatures from -30° F. at Flagstaff to -15° F. at Tuba City. Perhaps the most striking feature of the climate is the amount of sunshine, the State of Arizona as a whole averaging 222 clear days a year.

The rainfall over the Little Colorado Sub-Basin is very light and varies, more or less, directly with the altitude. The extremes of average annual rainfall recorded are a maximum of 12.1 inches at Flagstaff and a minimum of 6.7 inches at Tuba City. Rainfall generally occurs during the late winter and midsummer months--at times with great but local intensity. An irregular rainfall in an extremely arid climate, with the complicating feature of sparse vegetation to retard the runoff, causes the intermittent stream discharge pattern characteristic of the sub-basin.

The Little Colorado, and its mountain tributaries, rise as crystal clear streams that ordinarily are quickly absorbed as they reach the sands of the lower channels. Year-round flows are found only at the higher elevations. During extended rainy periods, however, the Little Colorado and many of its tributaries are flowing, turbid streams over their entire length and often become raging, chocolate-colored torrents with the more severe storms. At the lowest gage on the main-stem of the Little Colorado, located 96 miles above the mouth but below all but one tributary of consequence, prolonged periods of zero flow are recorded every year. During 1938, no flow was recorded at this point on 213 days. At the other extreme, a flow estimated at 120,000 second feet occurred at this point on September 19, 1923. The average annual discharge of the Little Colorado River is 338,000 acre-feet.

The silt burden of the Little Colorado and its tributaries is extremely high. Water samples collected from one, the tributary Oraibi Wash, have contained as much as 44 percent, by volume, of silt. The vegetation over most of the sub-basin is very sparse which, coupled with an extremely friable soil, accounts for the very heavy silt burden of the streams. Luxurious growths of marginal vegetation, which consume large quantities of water, develop along the permanent watercourses. It is estimated that more than 98 percent of the sub-basin's rainfall is lost by transpiration, evaporation, and seepage.

The surface water flows are of high quality near their point of origin. Mineral springs are common, however, and the dissolved solids content of the river water rises sharply due to these sources and due to the natural salt-bearing formations which are traversed downstream. The water generally becomes unfit for irrigation near the mouths of the streams. The waters of the main-stem Little Colorado are of questionable quality; because of dissolved salts below St. Johns and, a short distance below Holbrook, they are entirely unsuitable for irrigation.

The ground water resources of the sub-basin have not been intensively explored but are believed to be too limited to support much development of any major demand such as irrigation.

Virtually no white settlement of the sub-basin developed until the last quarter of the nineteenth century when the Santa Fe Railroad was constructed along the Rio Puerco and, for a short distance, along the Little Colorado. The four principal cities of the sub-basin, Gallup, Holbrook, Winslow, and Flagstaff, developed as railroad service points. The population of this sub-basin still remains very sparse as evidenced by a density (1950) of three inhabitants per square mile in comparison with a national average of 50.

Tourist service, grazing, lumbering, and agriculture constitute the principal industries of the sub-basin. Agriculture is completely dependent upon irrigation and is centered primarily in the upper Little Colorado and Zuni River Valleys. Manufacturing is relatively minor in the sub-basin. Only 979 employees

were so engaged in 1939 and the increased value of products added by the manufacturing processes amounted to $1,078,000 that year. Gypsum, salt, coal, bentonite, oil, and some manganese constitute the potential mineral resources of the sub-basin, none of which is extensively worked.

The principal use of the limited surface water within the Little Colorado River sub-basin is for irrigation. The quantity of water available will not permit extensive irrigation as evidenced by the fact that with all suitable firm water being used, less than 0.3 percent of the sub-basin area is under irrigation and the average value of all farm lands and buildings in 1946 was only $1.39 per acre in comparison with the national average of $31.71.

Only one community within the Little Colorado Sub-Basin (Winslow, Ariz.) utilized surface waters exclusively for domestic supply for an estimated 7,000 consumers. Three other communities in Arizona (Flagstaff, St. Johns, and Eager) supplement spring and ground water sources with surface water in serving a combined population estimated at 13,110. The consumption of domestic water from all sources in the six sub-basin communities for which data are available averages 65 gallons per day per consumer.

In 1945, there were two hydroelectric power plants with a total installed capacity of 125 kw. located within the sub-basin. The intermittent character of stream flows does not lend itself to power development and, in addition, there is little market for power owing to the scattered population and the lack of industrial development.

In the sub-basin, there are 18 reservoirs, with individual capacities exceeding 1,000 acre-feet, with a total storage capacity of 116,000 acre-feet. All of these impoundments serve agricultural uses. In addition, two supply municipal water and one serves a combination of agricultural and power uses.

Because of the intermittent character and the extremely heavy silt load of the streams in the Little Colorado Sub-Basin, recreational use of the water is relatively minor and virtually confined to the clear permanent streams of the mountains.

There are no known instances wherein man-made pollution has prevented any use of the waters of the Little Colorado Sub-Basin. Some localized contamination of surface water is believed to occur, notably in certain intermittent streams and irrigation ditches, as a result of the lack of convenient sanitary facilities. This constitutes a potential health hazard to isolated inhabitants downstream utilizing these waters as sources of domestic supply without treatment. Some nuisance conditions are reported from the effluents from inadequate sewage treatment plants which are discharged into dry washes. These situations are objectionable from the standpoint of aesthetics and may pollute the underground waters. The Arizona State Department of Health regards with considerable suspicion, the underground water sources in many parts of the Little Colorado River Sub-Basin.

Administratively, questions of health and sanitation on the extensive Hopi and Navajo Indian Reservations, which constitute a considerable portion of the Little Colorado Sub-Basin, are the responsibility of the Federal Office of Indian Affairs. The State Departments of Health exert jurisdiction only upon invitation by the Federal Government.

Although 23 of the 24 municipalities of the sub-basin now have sewage treatment facilities, 20 of the plants can no longer produce a satisfactory effluent because of overloading or obsolescence. It is estimated that one new sewage treatment plant is needed and 20 others must be enlarged or replaced before satisfac-

Table A_5. Sources of pollution, municipal

Municipalities*	Sources of pollution (in number of municipalities)	Population served by sewerage system	Amount of pollution discharged to watercourse (in terms of equivalent number of people)**
Having data on pollution load discharged to watercourse	0	--	--
Having population data available (Data on pollution load to watercourse incomplete or not available)	24	33,059	Not applicable
Total	24	33,059	--

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

**Includes industrial wastes discharged into municipal sewerage systems.

tory treatment of sewage can be secured. The cost of constructing these needed facilities is estimated to be $1,480,000. This cost does not include operation or maintenance or items influenced by local conditions such as land, rights-of-way, sewers and appurtenances.

Table B_5. Sources of pollution, industrial*

Industries	Sources of pollution (in number of plants)	Amount of pollution discharged to watercourse (in terms of equivalent number of people)
Producing organic wastes	0	--
Producing organic wastes	4	Undetermined
Producing inorganic wastes	--	Not applicable
Producing wastes of undetermined type	--	Undetermined
Total	4	--

*Industries having separate outlets and discharging wastes directly to watercourse.

Table C_5.
Existing treatment facilities, municipal

Degree of treatment provided	Number		Population served
	Municipalities*	Plants	
Primary	18	18	21,832
Secondary	5	5	3,612
No treatment	1	--	7,615

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

Table D_5. Existing treatment facilities, industrial*

Type industry	Number of plants	Number of industrial plants having:		
		Treatment facilities	No treatment facilities	Undetermined facilities
Food (milk).....	4	0	4	0

*Industries having separate outlets and discharging wastes directly to watercourse.

Table E_5. Adequacy of existing treatment facilities

Existing treatment facilities	Number	Adequacy with relation to:					
		Capacity			Operation		
		Satisfactory	Unsatisfactory	Undetermined	Satisfactory	Unsatisfactory	Undetermined
Municipal	23	3	20	0	8	15	0
Industrial	0	--	--	--	--	--	--

Table F_5. Progress in pollution abatement

Year	Municipal		Industrial	
	Plants completed	Design population	Plants completed	Amount of waste treated (in terms of equivalent number of people)
1946	0	--	0	--
1947	0	--	0	--
1948	0	--	0	--
1949	2	5,000	0	--

Table G_5. Requirements for municipal and industrial waste treatment plants*

Requirements	Municipal		Industrial
	Number	Population served by facilities	Number
New plant	1	7,615	4
Enlargement or additions to existing plant	6	3,170	--
Replace existing plant	14	11,762	--
No project required	3	10,512	--
Undetermined	0	--	--

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

Note: There are also 7 communities in this sub-basin with a combined population estimated at 5,355 for which State pollution control agencies recommend both sewers and treatment facilities although the municipal wastes are not discharged directly to watercourses.

Table H_5. Status of treatment works project to abate pollution, July 1, 1950

Status of project	Number	
	Municipal	Industrial
No formal action	21	4
Abatement ordered	--	--
Plans under preparation	--	--
Final plans approved	--	--
Construction awaiting financing	--	--
Under construction	--	--
Status undetermined	--	--

Table I$_5$. Project list - municipalities and industries requiring improvements for abatement of pollution*, July 1, 1950

Name	Population served**	Project requirements	Remarks
ARIZONA			
Municipalities:			
Fort Defiance	2,500	Replace plant	--
Ganado	700	Enlarge plant	--
Cameron	30	Additions to plant	--
Oraibi	200	Replace plant	--
Cornfield(Indian school)	75	Replace plant	--
Springerville	750	Replace plant	Should serve 1,500
Greasewood (Indian school)	125	Replace plant	--
Window Rock	250	Enlarge plant	--
Kim Li Chee (Indian school)	75	Replace plant	--
Petrified Forest National Monument	500	Replace plant	--
Petrified Forest National Monument	100	Replace plant	--
Klagotah (Indian school)	150	Addition to plant	--
Flagstaff	7,615	New plant	Should serve 10,000
Moenkopi	100	Replace plant	--
Tuba City	2,000	Enlarge plant	--
Pine Springs	40	Additions to plant	--
Keams Canyon	455	Replace plant	--
Steamboat(Indian school)	120	Replace plant	--
Pinon	200	Replace plant	--
Wide Ruin (Indian school)	70	Replace plant	--
Winslow	6,492	Replace plant	--
Industries:***			
A	--	New plant	--
B	--	New plant	--
C	--	New plant	--
D	--	New plant	--

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

**For industries this figure represents the population equivalent of their wastes.

***The industries listed herein have been coded in deference to the wishes of the Arizona State Health Department.

Note: The Arizona State Department of Health reports many communities and suburban developments that may pollute both ground and surface waters but are not included in this table as they lack communal sewage systems.

SAN JUAN RIVER SUB-BASIN

The San Juan River Sub-Basin is an area of approximately 19,700 square miles located in the northeastern corner of Arizona, the northwestern corner of New Mexico, the southwestern corner of Colorado and the southeastern corner of Utah. The sub-basin is approximately equally apportioned among the four States. A peculiarity of this sub-basin is the tableland surrounding it and appearing as "mesas" within it. The sub-basin is surrounded by a plateau which except for that northeastern portion located in Colorado is at a comparatively uniform elevation of 7,000 to 8,000 feet. In this northeastern portion the high peaks of the Rocky Mountains form the rim. A few of these peaks are more than 14,000 feet above sea level, others are above 13,000 feet and many more are at lower elevations.

Deep canyons drain the sub-basin. These canyons originate among the high peaks, continue across the plateau land varying in depth from a few hundred to more than 2,000 feet. The average elevation of the plateau land within the sub-basin is approximately 5,000 feet, whereas the outlet of the sub-basin, at the junction of the San Juan and the Colorado River has an elevation of about 3,300 feet.

Almost the entire runoff from this sub-basin originates in the high mountainous section of Colorado where over a limited area a 30-inch annual rainfall occurs. Further to the south and west, the rainfall decreases to an average of six inches per year. Most of the sub-basin is included within the eight-inch annual rainfall line.

The Animas River, which flows to the south from the northeast corner of the sub-basin, contributes an average annual flow of 1,028 second feet (33-year record). The San Juan above its junction with the Animas, draining an equal area, contributes an average annual flow of 1,469 second-feet (19-year record). The sum of these two flows constitutes the major portion of the recorded flow of the San Juan at Bluff, Utah above the junction with the Colorado River. At this station the 23-year average flow is 2,862 second-feet.

The average July temperature, for the entire sub-basin, approximates 74° F. However, this temperature will vary between wide limits due to the presence of the high mountains and flat, dry desert plains. The average January temperature approximates 26° F.

The total population of this watershed is 72,100 (1950 census) which gives a population density of 3.6 persons per square mile. The more humid conditions and available water supply in the northeastern part of the sub-basin has influenced the development of most of the communities along the upper reaches of the river.

A total of 15 communities have public water systems which serve an estimated population of 21,600. Five of these communities with a total population of 3,300 use ground water as a source of supply, one utilizes both ground water and surface water and the other nine, with a total population of 17,200, use surface water entirely. The total water consumption approximates 5.5 million gallons per day.

By far the greatest water use in this sub-basin is for the irrigation of agricultural lands. Other uses, although of importance, constitute but a small part of the total. The water in the upper reaches of the river is of good quality and has been used for irrigation purposes for the past 40 to 60 years.

There are 214,000 acres of land irrigated within this sub-basin. Of these, 30,000 acres are under the administration of the Office of Indian Affairs and are reserved for use by Indians that inhabit large reservations located within or adjacent to the sub-basin.

The drainage from the southern and western part of the sub-basin, with its infrequent rainfall, is intermittent and for long periods there is no flow recorded in many of the tributaries. The sparse vegetation gives scant protection to the friable soil, particularly in this precipitous area. As the stream and its tributaries pass through the plateau land, in their long course to the Colorado River, they gather tremendous silt loads resulting in the San Juan being credited with contributing one of the major silt loads to the Colorado River. For example, a tributary in the San Juan watershed is reported to have carried 47.1 percent silt by volume. Further, the Navajo Indian Reservation, located in the San Juan and the Little Colorado watersheds, (constituting 14 percent of the total Colorado River Basin area) contributes 22 percent of the silt but only 2.5 percent of the water to Lake Mead.

Reports of the State water pollution control authorities indicate a need for only three new municipal sewage treatment plants, the replacement of four others, and the enlargement of three others to remedy localized pollution problems. The estimated total cost of these improvements is $272,000.

There is a small amount of industrial waste pollution. However, the effect of this pollution has not been evaluated up to the present time. The industries involved are oil refineries,

meat packing plants, dairy plants and mining mills. Mining mill wastes from radioactive ores may prove to have particular significance in this river sub-basin.

Table A_6. Sources of pollution, municipal

Municipalities*	Sources of pollution (in number of municipalities)	Population served by sewerage system	Amount of pollution discharged to watercourse (in terms of equivalent number of people)**
Having data on pollution load discharged to watercourse	0	--	--
Having population data available (Data on pollution load to watercourse incomplete or not available)	15	19,007	Not applicable.
Total	15	19,007	--

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

**Includes industrial wastes discharged into municipal sewerage systems.

Table B_6. Sources of pollution, industrial*

Industries	Sources of pollution (in number of plants)	Amount of pollution discharged to watercourse (in terms of equivalent number of people)
Producing organic wastes	0	--
Producing organic wastes	1	Undetermined
Producing inorganic wastes	0	Not applicable
Producing wastes of undetermined type	50	Undetermined
Total	51	--

*Industries having separate outlets and discharging wastes directly to watercourse.

Table C_6.
Existing treatment facilities, municipal

Degree of treatment provided	Number		Population served
	Municipalities*	Plants	
Primary	10	10	9,778
Secondary	2	2	4,000
No treatment	3	--	5,229

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

Table D_6. Existing treatment facilities, industrial*

Type industry	Number of plants	Number of industrial plants having:		
		Treatment facilities	No treatment facilities	Undetermined facilities
Food and allied.....	5	1	--	4
Petroleum and coal.....	3	--	--	3
Primary metals.....	43	--	--	43
Totals.....	51	1	--	50

*Industries having separate outlets and discharging wastes directly to watercourse.

Table E_6. Adequacy of existing treatment facilities

Existing treatment facilities	Number	Adequacy with relation to:					
		Capacity			Operation		
		Satis-factory	Unsatis-factory	Unde-termined	Satis-factory	Unsatis-factory	Unde-termined
Municipal	12	5	7	0	6	5	1
Industrial	1	--	--	1	--	--	1

Table F_6. Progress in pollution abatement

Year	Municipal		Industrial	
	Plants completed	Design population	Plants completed	Amount of waste treated (in terms of equivalent number of people)
1946	0	--	0	--
1947	0	--	0	--
1948	0	--	0	--
1949	1	2,160	0	--

Table G_6. Requirements for municipal and industrial waste treatment plants*

Requirements	Municipal		Industrial
	Number	Population served by facilities**	Number
New plant	3	5,229	--
Enlargement or additions to existing plant	3	6,190	--
Replace existing plant	4	1,185	--
No project required	5	6,403	--
Undetermined	0	--	51

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

**Present sewered population.

Note: There is also one community in this sub-basin with a population estimated at 418 for which State pollution control agencies recommend sewers and treatment facilities although the municipal wastes are not discharged directly to watercourses.

Table H_6. Status of treatment works project to abate pollution, July 1, 1950

Status of project	Number	
	Municipal	Industrial
No formal action	9	--
Abatement ordered	--	--
Plans under preparation	--	--
Final plans approved	--	--
Construction awaiting financing	--	--
Under construction	1	--
Status undetermined	--	--

Table I_6. Project list - municipalities and industries requiring improvements for abatement of pollution*, July 1, 1950

Name	Population served	Project requirements	Remarks
Municipalities:			
Dennzhotso, Ariz.....	100	Additions to plant	--
Chinle, Ariz.....	400	Replace plant	--
Kayenta, Ariz.....	85	Replace plant	--
Lukachukai, Ariz.....	200	Replace plant	--
Rock Point, Ariz.....	90	Additions to plant	--
Aztec, N. Mex.....	500	Replace plant	Under construction
Cortez, Colo.....	2,651	New plant	--
Durango, Colo.....	6,000	Enlarge plant	--
Pagosa Springs, Colo.....	1,378	New plant	--
Silverton, Colo.....	1,200	New plant	--

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

GREEN RIVER SUB-BASIN

The Green River drains an area of approximately 45,000 square miles in southwestern Wyoming, northwestern Colorado and eastern Utah. The sub-basin is about 220 miles wide and 360 miles long, approximating the size of the State of Pennsylvania. The sub-basin is surrounded on the north, east and west by the high peaks of the Rocky Mountains, many of which are at elevations above 13,000 feet. The upper part of this sub-basin, in the State of Wyoming, is a broad valley with its floor at an approximate elevation of 7,000 feet. As the river leaves this upper valley, gathering its tributaries, it passes through a transitional zone of deep canyons for more than 200 miles until it discharges, at an elevation of approximately 5,000 feet, upon a second broad valley above the confluence with the Colorado River.

The primary source of water in this sub-basin is the precipitation that falls on the surrounding mountain peaks. Winter snows are stored in the mountain areas until the spring thaws release torrential floods.

The average annual precipitation over the sub-basin approximates ten inches. In the highlands of Utah the average may exceed 30 inches, across the sub-basin in the peaks of Colorado it may exceed 24 inches and in the high country of Wyoming 20 inches is recorded. In the southern part of the sub-basin, near the junction with the Colorado River where lower altitudes prevail, an average precipitation of six inches occurs. The river and its tributaries have such precipitous profiles and vast drainage areas that, despite the small total rainfall, a substantial river flow is discharged from the sub-basin each year. The stream gaging station which has been maintained, for the past 48 years, at Green River, Utah, 117 miles above the mouth, records an average flow of 6,740 second-feet, a maximum peak flow of 68,100 second-feet, and a minimum flow of 255 second-feet.

The present development of this sub-basin dates back to the Mormon pioneers who commenced irrigation at old Fort Supply in 1854 on Blacks Fork, an upper tributary to the Green. The Uintah Sub-Basin, which includes the watersheds of the Duchesne River and Ashley Creek, was set aside as an Indian reservation in 1861. In 1905 this reservation was opened to settlement and since that time it has experienced a pronounced growth. The high mountain ranges in the upper section, and the deep canyons of the southern or lower section isolated the Green River Sub-Basin in the past. Recent highway development has made this area less remote.

The population density within the sub-basin amounts to only 2.3 persons per square mile (1950 census). In general, the population is concentrated in the following areas, namely: the coal mining district in and about Price and Helper, Utah; the agricultural (and now oil producing) area in the Uintah valley which contains Vernal and Roosevelt, Utah; and the coal mining and railroad center in and about Rock Springs, Wyo. Outside of these areas there are some irrigation developments, small mining operations, and where there is sufficient precipitation to support natural forage, vast expanses of land used for cattle and other livestock grazing.

The urban population is served by 49 domestic water systems. Twenty of these systems serve 26,200 people from ground water sources. Twenty-four water systems are developed from surface water sources and serve 40,900 people. The remaining five community systems utilize both ground and surface water supplies and serve approximately 7,100 people. The combined total daily water consumption by these 49 systems is 9 million gallons, an important but minor use as compared to irrigation water requirements.

The principal economic pursuit is agriculture. In addition to the extensive grazing lands which support vast herds, there are 571,000 acres under irrigation. Completion of irrigation works now under construction will increase this total by 11,470 acres.

In eastern Utah there are 42 coal mines with a total employment of over 3,500 men. Coal mines are also operating in the Colorado and Wyoming sections of the sub-basin. In addition to coal there are known deposits of potash, asphalt, gilsonite, uranium, manganese, lead, copper, silver, leucite, limestone, trona, and salt. These deposits are worked to a varying extent but do not constitute a major economic resource of the sub-basin at this time. An important new economic development is that of petroleum production. The Rangeley, Colo. field contains about 1,200 wells but the number of producing wells could not be determined. The Ashley Oil Field near Jensen, Utah is a small but highly developed field. Recent discovery of oil and the completion of the first two wells on the Ute Indian Reservation promise to bring in a field of large proportions. None of these oil fields present serious brine pollution problems at the present time. However, this possibility should be periodically checked by State water pollution control authorities.

As might be expected, it is the areas with greatest population concentration that expe-

rience problems of surface water pollution. The Price River is grossly polluted by domestic sewage above Price, Utah. This condition can be corrected by the installation of an intercepter sewer and treatment plant to serve Helper and Price, Utah and the suburban population and small industries between Helper and Price.

The extension of sewers and the construction of a supplemental sewer system to serve a small industrial and residential area in Vernal, Utah would solve an irrigation water pollution problem. Other isolated problems exist in the sub-basin that are being corrected as rapidly as local finances permit.

The coal mines have not presented a serious pollutional problem to date because hydraulic cleaning methods are not used except in a few cases. In these few cases, because of water scarcity, water is re-used and recycled to the point that there is no flow to the drainage channels.

From existing limited information, mining and mining mill tailings do not appear to constitute a serious threat to water quality. However, the tailings dumps from some operations should be studied by State water pollution control authorities to determine if they are so located as to adversely affect water quality.

Some extensive water developments, in the form of large impounding reservoirs, are planned for the future. The largest of these are: Rattlesnake (2,000,000 acre-feet), Split Mountain (350,000 acre-feet), Echo Park (6,640,000 acre-feet), Red Canyon or Flaming Gorge Reservoir (4,180,000 acre-feet) and Cross Mountain (5,200,000 acre-feet). The purpose of these reservoirs are for irrigation, river regulation, power, sediment control, recreation, fish and wildlife conservation. Any one of these impoundments

Table A_7. Sources of pollution, municipal

Municipalities*	Sources of pollution (in number of municipalities)	Population served by sewerage system	Amount of pollution discharged to watercourse (in terms of equivalent number of people)**
Having data on pollution load discharged to watercourse	0	--	--
Having population data available (Data on pollution load to watercourse incomplete or not available)	32	49,131	Not applicable
Total	32	49,131	--

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

**Includes industrial wastes discharged into municipal sewerage systems.

Table B_7. Sources of pollution, industrial*

Industries	Sources of pollution (in number of plants)	Amount of pollution discharged to watercourse (in terms of equivalent number of people)
Producing organic wastes	13**	1,011
Producing organic wastes	4	Undetermined
Producing inorganic wastes	4	Not applicable
Producing wastes of undetermined type	36	Undetermined
Total	56	--

*Industries having separate outlets and discharging wastes directly to watercourse.

**Includes one oil refinery also producing inorganic wastes.

Table C_7.
Existing treatment facilities, municipal

Degree of treatment provided	Number		Population served
	Municipalities*	Plants	
Primary	18	18	20,265
Secondary	3	3	4,900
No treatment	11	--	23,966

*Includes incorporated or unincorporated municipalities; other legal bodies as sanitary districts, counties, towns; significant institutions, resorts, recreational centers, or other population centers, and industries discharging sanitary sewage wastes directly to watercourse.

will have a marked effect on water use in the sub-basin. Besides creating recreational facilities, the stream below such an impoundment will be materially improved by more uniform stream flow and by the reduction of much of the existing turbidity.

In the higher reaches of the stream the waters are clear, As the streams leave the higher and more rocky sections and after discharge upon the up-land plain, they become surcharged with silt to the point where they are roily, clay colored and opaque. Control of this condition will depend on up-stream soil retention, stream bed stabilization, tributary erosion control, and other factors. The development of information on water quality requirements would assist in the isolation of the individual problems and would furnish a basis to determine the eventual pollution capacity of these streams.

Pollution abatement has not progressed in this sub-basin to the extent that it has in the other sub-basins of the Colorado River Watershed. Treatment plants have been constructed by 21 of the 32 municipalities. Many of these plants have been outgrown by the communities they serve and now need enlargement or replacement. It is estimated that the proper treatment of municipal sewage will require the construction of 11 new plants, the replacement of ten existing plants and the enlargement of six others. The cost of doing this work is estimated to be $1,530,000 exclusive of opera-

Table D_7. Existing treatment facilities, industrial*

Type industry	Number of plants	Number of industrial plants having:		
		Treatment facilities	No treatment facilities	Undetermined facilities
Food and allied.....	16	1	15	0
Petroleum and coal.....	36	4	--	32
Primary metals.....	4	--	--	4
Totals.....	56	5	15	36

*Industries having separate outlets and discharging wastes directly to watercourse.

Table E_7. Adequacy of existing treatment facilities

Existing treatment facilities	Number	Adequacy with relation to:					
		Capacity			Operation		
		Satisfactory	Unsatisfactory	Undetermined	Satisfactory	Unsatisfactory	Undetermined
Municipal	21	5	16	0	6	14	1
Industrial	5	0	2	3	0	2	3

Table F_7. Progress in pollution abatement

Year	Municipal		Industrial	
	Plants completed	Design population	Plants completed	Amount of waste treated (in terms of equivalent number of people)
1946	0	--	0	--
1947	0	--	0	--
1948	0	--	0	--
1949	0	--	0	--

Table G_7. Requirements for municipal and industrial waste treatment plants*

Requirements	Municipal		Industrial
	Number	Population served by facilities	Number
New plant	11	23,966**	4
Enlargement or additions to existing plant	6	9,940	2
Replace existing plant	10	11,650	--
No project required	5	3,575	--
Undetermined	0	--	50

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

**Population served by present sewers.

Note: There are also 2 communities in this sub-basin, with a combined population estimated at 930 for which State pollution control agencies recommend both sewers and treatment facilities although the municipal wastes are not discharged directly to watercourses.

tion and maintenance. This cost does not include those items which vary widely with local conditions such as land costs, intercepting sewers, etc.

Four new industrial waste treatment plants are known to be needed and two existing plants require enlargement. The requirements of 50 industries known to be discharging wastes directly to the watercourses are unknown. The total number of industries that are operating in the sub-basin is still to be determined. This lack of definite information on the industrial waste pollution in the sub-basin precludes any estimate of the cost of necessary corrective measures.

Table H_7. Status of treatment works project to abate pollution, July 1, 1950

Status of project	Number	
	Municipal	Industrial
No formal action	26	6
Abatement ordered	--	--
Plans under preparation	--	--
Final plans approved	--	--
Construction awaiting financing	1	--
Under construction	--	--
Status undetermined	--	--

Table I$_7$. Project list - municipalities and industries requiring improvements for abatement of pollution*, July 1, 1950

Name	Population served**	Project requirements	Remarks
Municipalities:			
Green River, Wyo.	3,000	New plant	--
Kemmerer, Wyo.	1,600	New plant	--
Pinedale, Wyo.	400	Enlarge plant	--
Rock Springs, Wyo.	8,500	New plant	Awaiting financing
Craig, Colo.	2,250	Enlarge plant	--
Hayden, Colo.	540	Enlarge plant	--
Meeker, Colo.	800	New plant	--
Mt. Harris, Colo.	891	New plant	--
Steamboat Springs, Colo.	1,750	Enlarge plant	--
Castlegate, Utah.	400	Replace plant	--
Castledale, Utah.	1,000	Replace plant	--
Clear Creek, Utah.	200	Replace plant	--
Dragerton, Utah.	4,000	Enlarge plant	--
Ferron, Utah.	400	New plant	--
Green River, Utah.	375	New plant	--
Helper, Utah.	3,500	Replace plant	--
Hiawatha, Utah.	750	Replace plant	--
Huntington, Utah.	600	New plant	--
Kenilworth, Utah.	700	New plant	--
Latuda, Utah.	250	Replace plant	--
Price, Utah.	7,000	New plant	--
Roosevelt, Utah.	1,000	Enlarge plant	--
Spring Canyon, Utah.	1,000	Replace plant	--
Standardville, Utah.	450	Replace plant	--
Vernal, Utah.	4,000	Replace plant	--
Lyman, Wyo.	100	New plant	--
Myton, Utah.	100	Replace plant	--
Industries:***			
A.	303	New plant	--
B.	--	New plant	--
C.	--	New plant	--
D.	--	Enlarge plant	--
E.	--	New plant	--
F.	600	Enlarge plant	--

*The needs set forth in this table are based on presently available information. However, future studies and evaluations may result in some changes in these needs.

**For industries this figure represents the population equivalent of their wastes.

***Industries not named in deference to request by State pollution control agencies.

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